Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 191 JUNE, 1921 No. 6

THE APPLICATION OF RADIO TO NAVIGATION PROBLEMS.*

BY

REAR ADMIRAL W. H. G. BULLARD.

Director, Naval Communication Service, Navy Department, Washington, D. C.

LADIES AND GENTLEMEN: The excuse, or reason if you please, for my appearing before you this evening in the rôle of a lecturer, I lay entirely to your Secretary, Major Owens, who, I presume, took as a clue a remark accredited to the late Mark Twain, who, in dropping in to see an acquaintance, remarked that "having ten minutes to spare, he wished to inflict it on someone who had not the ten minutes to spare." I wish to pay tribute to the indefatigableness of your Secretary, for it was his persuasiveness and accomplishments of speech which worked on an unwilling subject and completely disarmed him, securing the promise of my appearing before this distinguished audience.

I approach the subject matter with considerable misgiving, for neither my training nor my education has been such that would cause me, of my own volition, to appear before a body of scientific men and women in the disguise of a lecturer. I have repeatedly thought that a course of public speaking or talking, if you please, should be included in a course at our National Academy, our Naval Academy, but my ideas along these lines have met with no sympathetic response. I have thought I should take up a course in public speaking, but was finally deterred by a previous

* Presented at a meeting of the Electrical Section held Thursday, November 4, 1920.

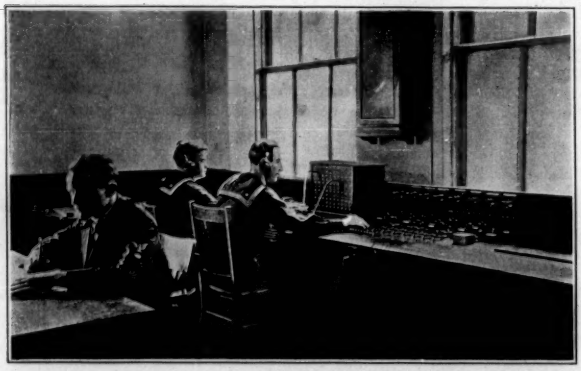
experience in trying to develop my memory. I purchased a set of seven books designed to improve the memory, and started in systematically to master the subject, and having gone laboriously and conscientiously through the first book, I laid them down and was never able afterwards to remember where I put them. So much for the success of reading the first volume, so I have given up all hope of improving my memory or the art of public speaking, and forgotten them both. I would rather you would think of what I have to say in the light of a talk, rather than a lecture, and I approach the various heads in which my talk divides itself as a user of apparatus rather than as a designer or engineer, as the service of which I have the honor to be the head is an administrative and operative service, not a designing or engineering one; therefore, what I have to tell you will be the practical side and not the scientific side. This may be disappointing to this scientific audience, but if so, you can lay your blame on him to whom I attribute my troubles, your Secretary, Major Owens.

I was asked to speak on the subject of radiotelegraphy as applied to the science of navigation, and the application of this science to the operation of saving life or property at sea.

One of the first applications of radiotelegraphy as an aid to navigation, aside from the simple transmission of radio messages to and from ships relating to matters of distress, to which it is unnecessary to refer, and one of the simplest applications, was the sending out of the so-called time signals at stated intervals. Time is an important element in navigation, and one of the two coördinates which fixes the position of a ship at sea, namely, longitude, is determined entirely from the element of time. Difference of longitude is only a question of difference of time, and the actual longitude measured from a given meridian is the difference between the times measured from that meridian and the local time. The time carried by mariners is obtained from a delicate chronometer, which is regulated to Greenwich Mean Time, and which, if absolutely correct, registers the correct mean time, counting the meridian of Greenwich, England, as the zero point. Knowing this time and the local time, the determination of the longitude resolves itself into a question of arithmetic, and the difference of time, and hence the longitude, is at once known. Ship chronometers, however, are subject to errors and rates, and these errors and rates must be determined to apply to the clock face

time in order to obtain the correct Greenwich Mean Time. The finding of the local time is a question of observing a heavenly body's altitude, and applying appropriate formulæ. Thus it is seen how important it is to know the correct Greenwich Mean Time, as the local time is easily obtained by observation.

Correct 75th meridian time is kept at the U. S. Naval Observatory, and it becomes the problem of carrying this time to ships at sea, so the errors of the mariners' chronometers on 75th meridian time and hence on Greenwich or zero mean time may be known. This error applied to the clock time gives the correct Greenwich Mean Time. This correct 75th meridian time is sent from the Naval



Central control station, Navy radio, New York.

Observatory by means of radio signals. Five minutes before each noon local 75th meridian time, a telegraph circuit is associated with the pendulum of the master clock at the Observatory, and a relay at the Arlington radio station. Once each second the electric circuit is momentarily closed by the circuit maker of the clock's pendulum and the relay at the radio station is energized. This closes a switch which permits a radio dot to be broadcasted into the ether. All ships having radio receiving sets tuned to receive Arlington's wave, receive this signal as a dot in the telephone receivers. Signals are started out five minutes preceding noon 75th meridian time, and a dot is sent once each second, with a break in the dots on the 29th second and the last five seconds of

each of the first four minutes, and finally the last ten seconds of the last minute. The time of exact noon, or the instant of 75th local noon, is a little longer contact after the ten-second break. The mariner marks the time shown by his chronometer and hence knows at once his error. It is advisable to check the time this way every day, but if this is impossible it should be taken after a lapse of several days, and with the two errors and the elapsed time the rate is known, which, applied to the error in one day, will give the error for any succeeding day. Time signals are sent out broadcast by the following stations on the Atlantic, Pacific and Gulf coasts in the United States:

Washington.—Daily at 11:55 A.M. to noon and 9:55 to 10 P.M., standard time, 75th meridian.
Key West.—Same as Washington.
New Orleans.—Daily at 11:55 to noon, standard time, 75th meridian time.
Darien, C. Z.—Daily at 12:55 P.M. to 1 P.M., 75th meridian standard time.
North Head, Wash.—Daily, except Sundays and holidays, at 11:55 A.M. to noon, 120th standard meridian time.
Eureka, Cal.—Same as North Head.
Point Arguello, Cal.—Same as North Head.
San Diego, Cal.—Same as North Head.
San Francisco, Cal.—Daily at 11:55 A.M. to noon and 9:55 to 10 P.M., 120th meridian standard time.
Great Lakes, Ill.—Daily at 10:55 A.M. to 11 A.M., 90th meridian standard time.

Time signals sent out from Washington, Key West and New Orleans, are from the Naval Observatory at Washington; those from the Pacific coast stations from the Naval Observatory at Mare Island, Calif. Signals from Darien, in the Canal Zone, are sent out from a master clock there, which is regulated each day by the signals sent out from Key West, and is thus sent one hour later. This is for the benefit of shipping in the vicinity of the Canal Zone, that cannot receive Key West.

Some European administrations send out time signals in a manner similar to that described, but most of them use different systems of dots and dashes, with the result that mariners must have the different signals sent out from each particular station. An international system would be highly desirable, so that a ship of any nationality could receive the signals under one common system, but efforts to bring about this desirable procedure have not yet proved successful. The French use a system that would be highly desirable, as it is so designed that fractions of a second

of time may be easily obtained, but this system does not well adapt itself to transmission by telegraph lines. The time signal system by radio, and certainly for land use, has probably been in existence in the United States longer than in any other country, and to change the system of receiving would disturb the thousands of customers who now use it. Its simplicity recommends it, and it is doubtful whether the more complicated, but scientific system, would be favored by the thousands of ships that now daily get their time.

Even the master clocks at the Observatories may have an error, and this is sent out from time to time; there is also an error introduced by the lag, due to the various relays the electrical circuit traverses. This is constant for a given station, and is published for the information of all. Thus the lag of the time signal sent from Key West is .07 of a second on the actual time, and which must be allowed for.

Connected with the general subject of time signals, but not related to the general question of navigation at sea, but of which I wish to speak for a moment, is the determination of the difference of longitude by means of radio signals. Interchange of radio signals between two stations furnishes a ready means of determining the difference of longitude between the two stations. This furnishes an added means of testing out a survey that has been made by triangulation from certain fixed points, and affords a ready means of quickly determining the difference of longitude between two points, by setting up temporary portable wireless sets. This method is particularly valuable in regions where triangulation is carried on with difficulty, and offers a means of obtaining differences of longitude over greater differences than can be served by instruments involving human sight.

Such a determination of the difference of longitude between observatories at Washington and Paris, was carried out by French and American observers in the fall and winter of 1913–1914. The radio signals were sent out both from the United States Arlington radio station, at Radio, Virginia, and the radio station at Eiffel Tower in Paris.

THE PROGRAM AND METHODS OF RADIO WORK.

At each station the program of radio work was essentially the same. At Radio, for example, the Leroy clock controlled the emission apparatus so as to send out three series of 420 signals,

called rhythmic signals, omitting, for purposes of identification, the 60th, 120th, 180th, 240th, 300th, and 360th signals.

As the Leroy transmitting clock did not automatically omit any signals, it was necessary for one of the radio observers to effect these omissions by the manipulation of a switch in the circuit from this clock to the sending apparatus. The omitted seconds are referred to as interruptions.

The intervals between successive signals were approximately $0^{s}99$ mean time, and each signal was about $0^{s}5$ long, a long signal being considered better than a short one by the radio observers when working with faint signals. This made it necessary for the radio observer to concentrate his attention on the beginning of the signal. In order to increase the number of coincidences that could be observed in the limited time during which uninterrupted use of the ether could be secured, it was planned to compare the rhythmic signals with an intermediary mean-time chronometer beating half-seconds at each station instead of with the observatory standard clocks which emitted signals only once in two seconds. The chronometer was compared by the radio observer with the observatory clock before and after the radio work, which usually occupied a little over an hour. During this period dependence was placed on the rate of the chronometer. All these comparisons were made by the coincidence method by ear, by the use of telephone receivers. The principle underlying such comparisons is essentially the same as that of the vernier, in this case coincidence of divisions of time being established by ear and in the case of the vernier the coincidence of divisions of space being established by the eye. When comparing the rhythmic signals with the chronometer, coincidences took place about once in 50 seconds, and in the case of emission signals generally seven or eight were observed in a series. In comparing the chronometer with the observatory clock, coincidences took place about once in three minutes and in general four were observed in each comparison.

The work of the radio observer was to listen, for example, to the rhythmic and chronometer beats in his telephone receivers and to note by the chronometer face the time of a coincidence of beats, to record this, and then, picking up the count from the chronometer but counting on the rhythmic beats, to count up to the next omitted signal in the rhythmic series, called an interruption, to record this,

then to observe the next coincidence, and so on to the end of the series. By means of an induction coil the chronometer signals were reduced in intensity, when necessary, until they were of about the same faintness as the radio signals. The observation of the interruptions was especially difficult in the case of the over-sea signals, since many of tnese signals were not heard. However, if one interruption in a series was observed, the rest could readily be supplied; and, even if none was observed, it was an easy matter to supply them all, assuming that the longitude was already approximately known.

By means of the records of the coincidences and of the interruptions, it was possible to determine from each observed coincidence the chronometer time of any signal in the series of rhythmic signals which might be selected as the reference signal. This was done for each coincidence and the mean was used. In order to eliminate from the mean the effect of error in the adopted rate of gain of the emitting clock on the comparing clock, due to errors of observation, the signal whose number in the series corresponds to the mean of the numbers of the signals at which coincidences were observed was taken as the reference signal. As this number is different for the two stations, the signal corresponding to the mean of the two numbers was used as the reference signal, thus rendering such errors negligible, though not completely eliminating them.

Having thus determined the chronometer time of a certain reference signal in a series, this was transposed into Riefler clock time by means of the comparisons between the chronometer and the clock and was then transposed into local sidereal time by the application of the clock correction. In cases where the rhythmic signals were observed at both stations we have, then, the local sidereal time of a given reference signal at each station, and the difference is the longitude except as affected by transmission time, the effect of which is to make the longitude determined by signals emanating from Washington too large and those determined by signals from Paris too small by the time occupied in transmission.

The errors of the clocks involved were checked each night by a continuous succession of star observations to determine the correct sidereal time.

Taking account of all errors of whatever kind, and the personal errors of the observers, and the fact that the personnel in-

volved interchanged their duties between Washington and Paris, the final difference of longitude was determined to be:

$5^h\ 17^m\ 36^s.653 \pm s0031.$

THE WASHINGTON-GREENWICH LONGITUDE.

The Washington-Paris longitude given in the American Ephemeris and Nautical Almanac from 1901 to 1915, $5^h\ 17^m\ 36^s.75$, is correlated with the Paris-Greenwich longitude, $0^h\ 9^m\ 20^s.97$, which has been superseded by the value given above, corresponding to a Washington-Paris longitude of $5^h\ 17^m\ 36^s.71$. This depends on the adjustment of the Washington-Greenwich longitude made by Schott in 1897, which gave for that longitude $5^h\ 8^m\ 15^s.78 \pm 0^s.05$. Schott's value was based largely upon the result of the 1892 cable determination of the difference of longitude between Montreal, Canada, and Greenwich, for the result of which only the preliminary value was available when the adjustment was made. The definitive value gave a correction to the preliminary value of $-\ 0^s.05$, indicating that Schott's value of the Washington-Greenwich longitude is somewhat too large. Assuming the value given above for the Greenwich-Paris longitude, and combining with it the Washington-Paris longitude resulting from the present determination, the following value is obtained for Washington-Greenwich:

$5^h\ 8^m\ 15^s.721 \pm 0^s.014.$

The French authorities have proposed that an extension of their first experiment be repeated with other stations, and it will be interesting to see how near the difference of longitude carried around the world will check up to 24 hours.

WEATHER REPORTS.

An important element in safe navigation at sea is information respecting weather conditions that may be expected within a certain region in which a ship is likely to find itself. Daily weather bulletins relating to the North Atlantic Ocean, the Gulf of Mexico, the Great Lakes, and the Pacific Ocean, prepared by the United States Weather Bureau, are sent broadcast by naval radio stations as follows:

The bulletins begin with the letters U.S.W.B. for the United States Weather Bureau, and the weather conditions follow. The first three figures of the report represent the barometric pres-

sure in inches (0.02 = 30.02); the next figure, the fourth in sequence, represents the direction of the wind to eight points of the compass: 1 = north; 2 = northeast; 3 = east; 4 = southeast; 5 = south; 6 = southwest; 7 = west; 8 = northwest; and 0 = calm. The fifth figure represents the force of the wind on the Beaufort Scale, running from 0 = calm, to 12 = hurricane. In order to simplify the code, no provision is made for wind force greater than 9 = strong gale, on the Beaufort Scale.

If the weather conditions from any one station cannot be supplied, the initial of the station is given, followed by the word "missing," and if any portion of a report cannot be furnished, such portion is replaced by an equivalent number of letters x.

The second part of the bulletin consists of wind and weather forecasts and, whenever conditions warrant, information as to storm-centres, storm and hurricane warnings, and advices to shipping. The wind and weather forecasts are for 24 hours, beginning at midnight. The zones to which the forecasts apply are identified by suitable charts. Whenever a storm exists that is likely to affect a section, the location and expected direction of movement of the storm centre will be given, followed by any storm or hurricane warnings and advices to shipping that have been issued.

EXAMPLE OF BULLETIN:

(First part.) USWB J 01662 S 00663 FP 98821 ML 95427 T 95846 NY 93258 DB 92888 LB 95612 CH 94216 H 94645 AV 98282 C 96682 B 00661, etc.

(Second part.) Winds off Atlantic coast north of Sandy Hook will be shifting gales with rain. Sandy Hook to Hatteras, northwest gales with rains followed by clearing weather. Hatteras to Florida Straits, strong northwest winds; fair weather. Storm of marked intensity central off New Jersey coast moving northeastward. Storm warnings displayed Hatteras to Eastport.

The second part of the bulletin is always in plain language and requires no translation. Suitable charts show the location of many of the regular observation stations maintained by the Weather Bureau on the continent and in the Gulf of Mexico, and the Caribbean Sea, within the confines of the map; also Canadian stations. Key letters are indicated under station reports from which are given radio distribution. These reports, supplemented by others picked up from vessels, can be used, as illustrated on the chart, in the production of quite a comprehensive weather map.

which will be of much value to navigating officers. Observations radiographed from vessels are in a code prepared by the Weather Bureau for "Vessel Weather Observers" and are easily translated by use of that code.

DISTRIBUTING STATIONS.

Atlantic Coast.

Following is a list of Naval radio stations from which distributions are made, and the composition of the bulletins distributed by them:

ARLINGTON, VA.: Sending time, a few minutes after 10 P.M., 75th meridian time. Wave-length, 2650 metres.

Observation stations contained in first part and code letters.	Second part of bulletin.
St. Johns, N. B. ..... J	(1) Winds off Atlantic coast north of Sandy Hook.
Sydney, N. S. ..... S	(2) Winds off Atlantic coast, Sandy Hook to Hatteras.
Father Point, Canada ..... FP	(3) Winds off Atlantic coast, Hatteras to Florida Straits.
Montreal, Canada ..... ML	Storm warnings, Eastport, Me., to Key West, Fla.
Nantucket, Mass. ..... T	Location and expected direction of movement of storm-centres affecting Atlantic coast.
New York, N. Y. ..... NY	All hurricane warnings and advices.
Breakwater, Del. ..... DB	Figures in brackets correspond to zones shown on appropriate charts.
Lynchburg, Va. ..... LB	Period covered by forecasts, 24 hours beginning at midnight.
Cape Henry, Va. ..... CH	
Hatteras, N. C. ..... H	
Asheville, N. C. ..... AV	
Charleston, S. C. C	
Bermuda ..... B	
Atlanta, Ga. ..... AT	
St. Louis, Mo. ..... SL	
Little Rock, Ark. ..... LR	
Nashville, Tenn. ..... NV	
Duluth, Minn. ..... DU	
Marquette, Mich. ..... M	
Chicago, Ill. ..... CH	
Detroit, Mich. ..... D	
Buffalo, N. Y. ..... F	
Cincinnati, Ohio ..... CN	

This station broadcasts about noon, 75th meridian time, all storm warnings issued in the forenoon for the Atlantic coast and Great Lakes; also broadcasts at night (during the season of navigation on the Great Lakes) the same bulletin distributed by the Great Lakes station and at approximately the same hour.

KEY WEST, FLA.: Sending time, a few minutes after 10 P.M., 75th meridian time. Wave-length, 1988 metres.

Observation stations contained in first part and code letters.	Second part of bulletin.
Hatteras, N. C. ..... H	(3) Winds off Atlantic coast, Hatteras to Key West.
Charleston, S. C. C	(4) Winds over east Gulf of Mexico (east of longitude 90°).
Jacksonville, Fla. ..... JA	(5) Winds over west Gulf of Mexico (west longitude 90°).
Miami, Fla. ..... MI	(6) Winds over Caribbean Sea (west of longitude 73°) and Windward Passage.
Key West, Fla. ..... K	Storm warnings Hatteras to Key West and for Gulf of Mexico.
Pensacola, Fla. ..... P	Location and expected movement of storm-centres affecting Atlantic coast south of Hatteras and Gulf of Mexico.
Burrwood, La. ..... BW	Storm warnings Gulf of Mexico, Key West to Brownsville.
Galveston, Tex. ..... GV	All hurricane warnings and advices.
Brownsville, Tex. ..... BV	Figures in brackets correspond to zones shown on appropriate charts.
Fort Worth, Tex. ..... FW	Period covered by forecasts, 24 hours beginning at midnight.
Kingston, Jamaica ..... KN	
Turks Island ..... TI	
Havana, Cuba ..... HA	
Guantanamo Bay, Cuba ..... GO	
Swan Island ..... SI	
San Juan, P. R. ..... SJ	

POINT ISABEL, TEX.: Sending time, midnight, 75th meridian time. Wave-length, 2250 metres.

Observation stations contained in first part and code letters.	Second part of bulletin.
Key West, Fla. ..... K	(4) Winds over east Gulf of Mexico (east of longitude 90°).
Tampa, Fla. ..... TA	(5) Winds over west Gulf of Mexico (west of longitude 90°).
Pensacola, Fla. ..... P	(6) Winds over Caribbean Sea (west of longitude 73°) and Windward.
Mobile, Ala. ..... MO	Storm warnings for Gulf of Mexico, Key West to Brownsville.
Burrwood, La. ..... BW	Location and expected movement of storm-centres affecting Gulf of Mexico.
Galveston, Tex. ..... GV	All hurricane warnings and advices.
Corpus Christi, Tex. CC	
Brownsville, Tex. ..... BV	
Kingston, Jamaica ..... KN	
Swan Island ..... SI	

Figures in brackets correspond to zones shown on appropriate charts.
Period covered by forecasts, 24 hours beginning at midnight.

SAN JUAN, P. R.: Sending time, 9 P.M., 75th meridian time. Wave-length, 2750 metres.

Distribution is made from this station only from June to November, inclusive.

Observation stations contained in first part and code letters.	Second part of bulletin.
San Juan, P. R. ..... SJ	All hurricane warnings.
St. Thomas, Virgin Islands .... ST	In the absence of a tropical storm the following words will be sent each day, "Weather Normal."
Basseterre, St. Kitts ..... BT	
Roseau, Dominica ..... RS	
Bridgetown, Barbados ..... BB	
Santo Domingo, S. D. ..... SD	
Puerto Plata, S. D. ..... SL	
Port au Prince, Haiti ..... HT	
Willemstadt, Curacao ..... W	
Port of Spain, Trinidad ..... PS	

Hurricane warnings also will be broadcast from this station at 10 A.M., 75th meridian time, or as soon thereafter as possible.

GREAT LAKES.

GREAT LAKES, ILL.: Sending time, shortly after 10 P.M., 75th meridian time. Wave-length, 1988 metres.

Distribution is made from this station only during season of navigation on the Great Lakes, approximately April 15th to December 20th.

Observation stations contained in first part and code letters.	Second part of bulletin.
Duluth, Minn. ..... DU	Forecasts for upper Lakes (Superior, Michigan, and Huron).
Marquette, Mich. ..... M	
Saulte Ste. Marie, Mich. ..... U	Forecasts for lower Lakes (Erie and Ontario).
Green Bay, Mich. ..... G	
Chicago, Ill. ..... CH	Storm warnings for upper and lower Lakes.
Grand Haven, Mich. ..... GH	
Alpena, Mich. L	Location and expected movement of storm-centres affecting the Lakes.
Detroit, Mich. ..... D	
Cleveland, Ohio V	
Buffalo, N. Y. ..... F	

Period covered by forecasts, 24 hours, beginning at midnight.

All storm warnings issued in the forenoon for the Great Lakes also are distributed from this station about noon, 75th meridian time.

Storm and hurricane warnings are displayed at over 200 points along the Atlantic and Gulf coasts, including every port and harbor of any considerable importance. Flags are used by

day and lanterns at night. Illustrations and descriptions of these signals will be found on pilot charts.

Pacific Coast.

Weather bulletins are obtained from the Weather Bureau at San Francisco by the San Francisco station about 6 P.M., and forwarded by radio to North Head and San Diego as soon as practicable. San Francisco, North Head, and San Diego radio stations broadcast this weather bulletin on the working wave, 952 meters and 600 meters, immediately after transmission of time signals, etc. All stations broadcast hydrographic information and storm warnings immediately after receipt, and at 8 A.M., noon, 4 P.M., and 8 P.M. (four-hour intervals immediately after receipt of message, except 4 A.M. and midnight). All stations also broadcast their local weather at 8 A.M., noon, 4 P.M., and 8 P.M. Cape Blanco broadcasts weather conditions at Tatoosh, North Head, and Eureka, immediately after broadcasting local weather report. At 8 A.M. and 8 P.M. Eureka broadcasts the 6 A.M. and 6 P.M. weather condition at Farallon Islands; Point Arguello broadcasts the 7 A.M. and 7 P.M. weather conditions at Farallon Islands; Farallon Islands broadcasts the 6 A.M. and 6 P.M. Eureka weather condition and the 7 A.M. and 7 P.M. Point Arguello weather condition.

The daily bulletin broadcasted by San Francisco, North Head, and San Diego, consists of two parts. The first part contains code words and figures which express the actual weather conditions at 5 P.M. (120th meridian time) on the day of distribution at certain points along the western coast of the United States. The second part of the bulletin contains a special forecast of the probable winds to be experienced a hundred miles or so offshore, made by the United States Weather Bureau, San Francisco, for distribution to shipmasters by naval radio as above. The second part of the bulletin also contains warnings of severe storms along the coast as occasion may arise.

The coast line of the western part of the United States is divided as follows:

Northern Pacific, Tatoosh to Cape Blanco.
Central Pacific, Cape Blanco to Point Arguello.
Southern Pacific, Point Arguello to San Diego.

The forecast and warning is in ordinary language, and covers a period of 24 hours from 5 P.M., date of issue. At the end of the forecast a statement is made in regard to the location and movement of any barometric depression that may be likely to affect the winds over the ocean.

Example of forecast and warnings:

Northern Pacific missing Central Pacific Wednesday rain heavy southeast winds Southern Pacific moderate southerly winds period Southeast storm warnings displayed Pointarguello to Capeblanco.

A new broadcasting service for the Pacific Coast is being arranged.

Hawaii.

Weather bulletins obtained from the United States Weather Bureau at Honolulu are broadcasted daily by the Pearl Harbor Radio Station at 8 A.M., noon, 4 P.M., and 8 P.M.

Tutuila, Samoa.

Local weather bulletins preceded by the letter "T" are broadcasted by the Tutuila Naval Radio Station at 8 A.M., noon, 4 P.M., and 8 P.M.

HYDROGRAPHIC INFORMATION.

Information concerning wrecks, derelicts, ice, and other dangerous obstructions to navigation whenever received from the Hydrographic Office or from a branch hydrographic office or other reliable source is sent broadcast four times daily, viz, at 8 A.M., noon, 4 P.M., and 8 P.M., local (standard) time of station. Ships within range of a naval radio station receive these hydrographic messages and refrain from sending radio messages at these times, knowing that one vessel sending may prevent several others receiving information necessary to their safety.

Naval radio stations furnish this information to passing vessels on request, at other hours than those mentioned. Should it not be practicable to send out this information on one of the hours mentioned, it is held until the next scheduled time and then sent broadcast.

Each day at noon, and at 10 P.M., 75th meridian time, immediately following the time signal, the Naval Radio Station at

Washington broadcasts such information relating to safe navigation as may be furnished it by the Hydrographic Office during the preceding 24 hours. The same wave-length, 2650 metres, used in the time signal, is employed.

In addition to the regular hydrographic information sent out from naval radio stations as a daily routine, special provision is made during the Spring months for furnishing information relating to the location of icebergs that drift from their northern breeding grounds, and which are liable to drift in the lanes of passenger steamers to and from Europe in the North Atlantic.

By a special agreement reached at the International Convention on Safety of Life at Sea, which met in London in the Fall of 1913, the United States obligated itself to cause a sea patrol to be kept in the steamship lanes where icebergs are liable to be found, and to report the presence and location of these icebergs to nearby vessels by proper radio reports. In addition to these reports, at least one daily report of icebergs is sent to Washington by radio either through Canadian or United States stations, and these in turn are broadcasted at stated intervals for the benefit of shipping that cannot be reached by the patrol vessel. All countries signatory to the Safety at Sea Convention bear their proportionate shares of the expense connected with this patrol. This patrol has been of the greatest help to mariners, and more than one vessel owes its safety to information given by the patrol vessel. By giving the exact location of dangerous icebergs, vessels are enabled to steer a course that will safely lead them from danger.

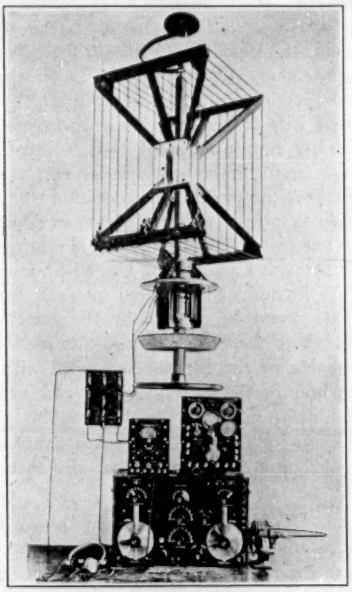
THE RADIO DIRECTION FINDER.

The name "Radio Direction Finder" is a name applied to certain electrical apparatus which is so constructed as to enable its operator to discover from what direction a given radio signal emanates. This apparatus is sometimes referred to as a "Radio Compass."

A few words illustrating the elementary principle upon which the radio compass functions may be desirable. If we imagine a vertical conducting wire as the antenna of a radio transmitting set, this will, on being properly energized, radiate a series of electric magnetic waves which may, for purposes of illustration, be considered as a series of concentric circles radiating from the

conductor as a circle, or, in other words, the lines representing the waves are closed circles. They expand at the speed of light and finally reach the receiving antenna of the radio compass.

From the well-known electrical theory that when a coil of wire is placed in a varying magnetic field, an E M F will be induced in the coil, and if the circuit is closed a current will flow,

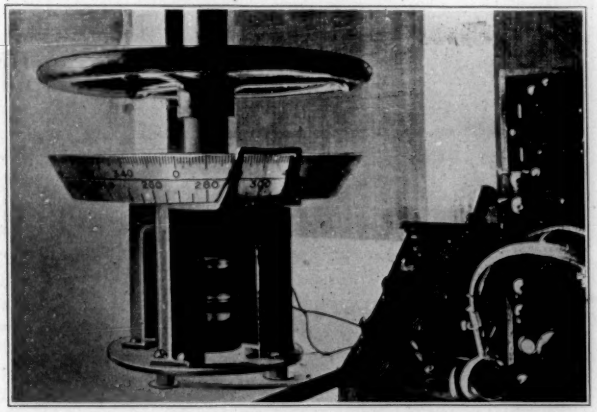


Radio compass receiving equipment.

the magnitude of the induced E M F will depend upon the number of lines of force that are actually cutting through the coil. If the coil is placed so that the magnetic lines go through it in a direction parallel to the turns of the coil, there will be no induced E M F, since there are no magnetic lines actually cutting through it. If, however, the coil is turned so that the magnetic lines thread through the coil in a direction at right angles to the turns of the coil, induction in the coil will be a maximum. The induced

E M F will tend to drive a current through the coil if the circuit is closed. In order that the presence of this current may be manifested, suitable means for tuning the circuit to make the current a maximum and for detecting it must be provided. Tuning may readily be accomplished by placing a condenser across the terminals of the receiving circuit.

Associated with the coil and the capacity across its terminals, is the receiving circuit, generally of a vacuum tube in connection with the head telephones. If the coil is so arranged that it may be rotated, there will be a position where there are no lines

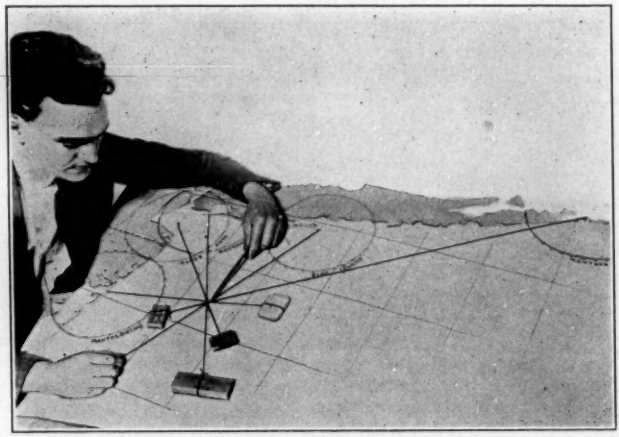


Close view of compass scale.

of force actually cutting the coil, there will be no induced E M F and no signal will be heard in the telephone. If the coil is turned through 90°, the number of cutting lines of force will be a maximum, and the signal heard in the telephone will be a maximum. This furnishes a ready means for determining the direction of the incoming signal. It will be seen that as the coil is rotated, there will be two positions of minimum signals and two of maximum, the minimum being 180° apart and the maximum 180° apart. If the minimum is taken as the point of observation, it is known that the transmitting station is in a direction at right angles to the plane of the coil when in the position corresponding

to minimum signals. The compass used in this manner determines one line of hearing, in which the ship emitting the signal must be. The general configuration of the land and surroundings determines which of the two bearings 180° apart is the one to be used. This method of operation is termed "bilateral," in which the signal strength undergoes the same variation twice in a complete revolution.

By obtaining two or more lines of bearing from separate stations, a ship's position is obtained by noting the intersection of



Bearings are quickly plotted at central control shore station before being forwarded to vessel concerned. This to assure precision.

the lines of bearing from each. If the apparatus is so arranged that one of the maxima is louder than the other, we may take either the louder or weaker maximum as the true direction of the ship's transmitter. If the coil is placed in a position corresponding to a signal of maximum intensity, with the plane of the winding parallel to the direction of the transmitter, an arrow may be attached to one side of the coil to aid in identification of this side. Now the coil may be completely turned around through 180°. The plane of the coil is again parallel to the original direction and the current of the coil is now at maximum, but is now flowing through

the circuit in the reverse direction. The only effect of reversing the coil is to reverse the direction of the current flowing through it; the signal strength remains the same. If it were possible to rotate on its axis a single wire forming the antenna, it would be found that the strength of the received signals remained the same, or, in other words, that the signal strength does not depend in any way upon the direction of the transmitting station. Such a system may be appropriately termed a non-directional system. If we have another current which does not reverse when the coil is reversed, the two currents will add in one position and in the other position will subtract. One maximum is thus strengthened and the other is weakened.

The unilateral method determines very roughly the absolute direction of the transmitting station, or, in other words, gives us the sense of direction. The readings may not be taken with any degree of accuracy, since the maxima are not well defined.

A combination of the two methods results in ideal operation, since one type balances up the weak points of the other. The general sense of direction is obtained with the unilateral, the antenna circuit is then disconnected and the bilateral method gives the accurate bearing. The information obtained with the unilateral method enables us to discard one of the maxima on the bilateral, giving the remaining maximum as the absolute direction of the transmitter. The general arrangement of the compass coil, with the necessary receiving attachments, is shown in the figure.

The perfected system of radio direction finding has been in use in the American Navy for a little over a year. A brief description will be given of the method of its use in a crowded neighborhood, as is found off the port of New York. It is assumed that a ship is off the port 80 or 100 miles, and maybe is in a doubtful position. The ship emits a signal by her radio "QTE" which, interpreted, means, "What is my true bearing?" This request, coming within the sector which the New York District Central Controlling Radio Station is responsible for, the appeal is received by five radio compass stations located at Montauk Point, L. I., Fire Island, Rockaway Beach, Sandy Hook, and Mantoloking, N. J., which are shown in the figure. Each of these stations is connected with the New York Central Control Office, at 44 Whitehall Street, by telegraph and telephone. These radio compass stations can not communicate with a ship, as they

have receivers only, and not transmitters. Each of the radio compass stations notifies the Control Station in Whitehall Street that a ship is asking for bearings. Immediately the Control Station radios to the ship to continue sending the ship's call letters for about 30 seconds. During this interval the radio compass stations begin obtaining bearings on the ship. The operators in the five stations turn their compass coils until each has an accurate bearing. These five readings are transmitted to the central station, where, on a large chart, the five readings are combined and

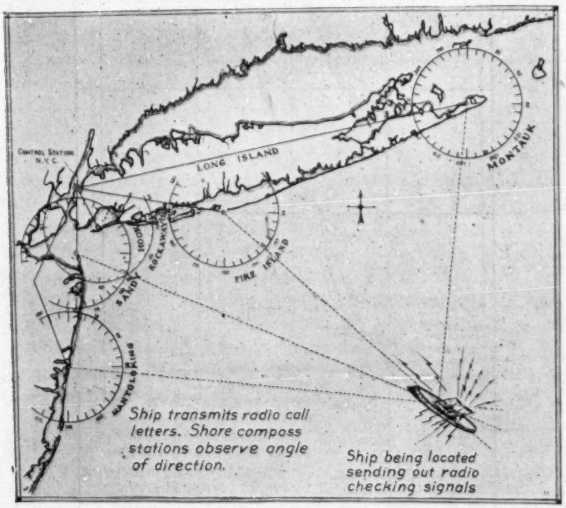
U.S. Chicago's test on compass stations in the Third Naval Dist. May 27-28 1918
Long Island
U.S.S. Chicago - Piloted by Radio Compass Bearings

Comparison of positions plotted by radio bearings with actual positions.

plotted. At the point of intersection of the various lines of bearing is the location of the calling ship. The main control office then transmits to the ship its bearings from each of two or more stations and the navigator on the ship can then plot his own bearings, find the intersection and know where the ship is located. Acknowledgment from the ship completes the operation, and the ship will then be able to set a safe course and proceed on its way. Various pictures are shown on the screen showing this operation.

These radio compass stations are now installed on the Atlantic, Gulf, and Pacific coasts, as well as on the Great Lakes, and stations are being constructed in Alaska and in all outlying posses-

sions. There are at present 47 compass sections built and ready for operation, and 27 more under construction. A general plan of the location of these stations is shown in the picture on the screen, showing how well our coasts are protected by these safety devices. There will be shown one or two examples of this operation and the great use it has been to mariners in saving lives and property. Also there is shown the track of a ship that made a voyage along the coast from Boston as far south as Charleston,


LONG ISLAND
MONTAUK
FIRE ISLAND
Ship transmits radio call letters. Shore compass stations observe angle of direction.
Ship being located sending out radio checking signals

Graphic representation of method used for obtaining radio compass bearings.

with her course accurately plotted by other navigational means than the radio compass, and during this trip the ship was located by radio compass bearings from various stations, which are also shown on the chart, showing how well these compass stations were able to keep track of the ship during this journey. The distance at which bearings are accurate within say half a degree, is probably at this time limited to distances between 75 and 100 miles, but constant improvements are being made, and as the skill of the operators increases, it is readily expected that these distances will be easily doubled with the same degree of accuracy.

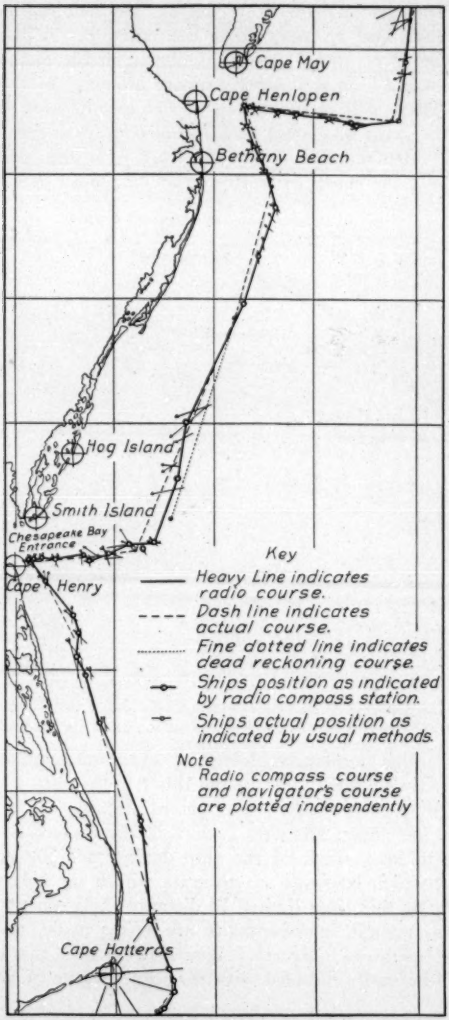


Chart showing test of radio compass shore stations by U. S. S. *Chicago*, Boston, Mass., to Charleston, S. C., May 26th to May 30th, 1919.

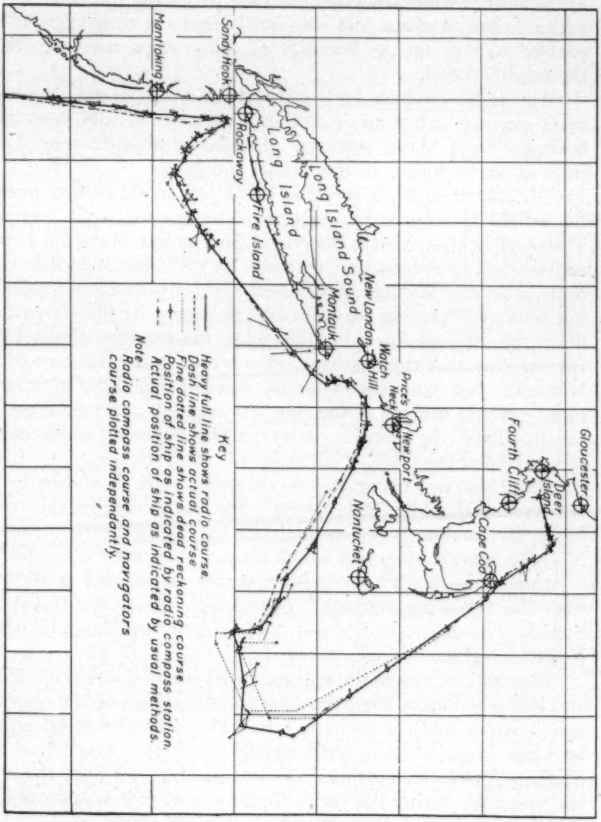


Chart showing test of radio compass shore stations by U. S. S. *Chicago* Boston, Mass., to Charleston, S. C. May 26th to May 30th, 1919.

In addition to shore stations being fitted as radio compass stations, naval ships themselves are also fitted with this apparatus, by means of which they are enabled to obtain the direction of various short stations, and thus easily locate themselves, and are enabled to pick up the bearings of other ships that may be in the neighborhood.

The radio compass finds especial use with aircraft, and aircraft may be safely navigated in flight, by giving them their bearings from shore stations. Similarly, aircraft may locate ships at sea by means of their radio compasses.

On July 6, 1920, a seaplane flight was made to demonstrate the reliability of aircraft navigation by use of radio compass. The seaplane was based at the Naval Air Station, Hampton Roads, and worked in conjunction with the U.S.S. *Ohio,* which is especially fitted as a floating radio laboratory for purposes of conducting tests and carrying on radio experiments. At the start of the flight the seaplane knew nothing as to the location of the *Ohio,* further than that the ship was in an arc of 100 miles centered at Norfolk. Just 5 minutes after the start of the flight an accurate radio compass bearing of the ship was secured, and 1 hour and 30 minutes later, the seaplane, after having flown 85 miles almost direct, circled the *Ohio.*

The *Ohio* was under way to the southward, as shown by the bearings obtained by the seaplane. The navigation, on the return flight to Norfolk, was accomplished by taking bearings on the Norfolk radio station, and which proved to be very accurate.

During the flight communication was maintained at all times with the following stations: The U.S.S. *Ohio,* the Naval Air Station, Anacostia, D. C., and Naval Operating Base, Hampton Roads, Virginia.

In addition, the radio compass stations at Cape May, N. J., and Bethany Beach, Virginia, took cross-bearings on the seaplane, and these proved to be very accurate. The plane also took bearings on Cape May, which proved equally accurate. The Naval Air Station, Anacostia, obtained compass bearings on both the *Ohio* and seaplane, during the entire flight, and later it was possible to plot the approximate courses of both ship and plane.

On the return flight from Norfolk, on July 7, bearings were taken on the *Ohio* by the plane at a distance of 175 miles, which is probably a record for this class of work, but greater distances can be obtained by increasing the power of the transmitting station.

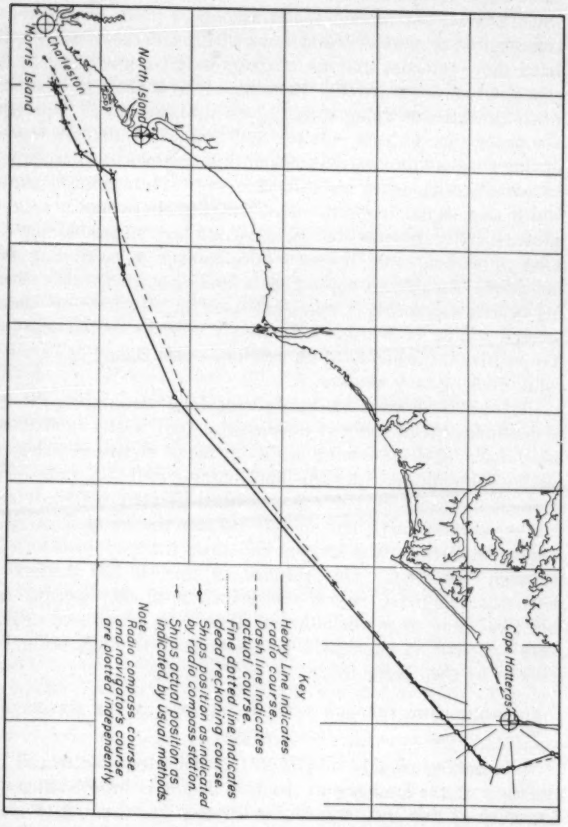

Charleston
Morris Island
North Island
Cape Hatteras
Key
Heavy Line indicates radio course.
Dash line indicates actual course.
Fine dotted line indicates dead reckoning course
Ships position as indicated by radio compass station.
Ships actual position as indicated by usual methods.
Note
Radio compass course and navigators course are plotted independently.

Chart showing test of radio compass shore stations by U. S. S. *Chicago*, Boston, Mass., to Charleston, S. C., May 26th to May, 30th, 1919.

The Aircraft Radio Laboratory has completed experiments and has found that the bearings from aircraft when observed by shore radio compass stations are accurate to within two degrees when aircraft are beyond a distance of 20 miles from compass stations, but that when aircraft are within a distance of 20 miles from shore compass stations, bearings vary considerably. In this experiment it was noted that when they received short wave signals, when aircraft was flying directly overhead, there was apparently a zone of silence from aircraft, and that when aircraft was receiving from a shore station transmitting, the effect was reciprocal. In other words, when aircraft flew over a transmitting station which sent signals on short wave lengths, there was a zone of silence directly over the station, and it has been suggested that this zone of silence could be used to advantage as a landing field indicator. As aircraft approaches a landing station and is receiving bearings from it, it may find itself in this zone of silence, when it will be known that it is directly over the station, and thus has positive information of its location. This should be very useful in thick or hazy weather.

The radio compass was very successfully used during the war to determine the presence of hostile ships, particularly submarines, which had a habit of coming to the surface at night and endeavoring to communicate with their home bases at night, by radio. The moment the radio started, compass bearings were obtained from one or more stations, and in this manner the location of these hostile submarines was known, and their track could almost be definitely followed. This resulted in time in the capture or destruction of many enemy submarines, until they became certain that some means unknown to them was being used against them and had no alternative but to keep silent, thus being lost track of by their home bases.

DIRECTING SHIPS THROUGH NARROW CHANNELS BY THE DIRECTIVE PILOT CABLE.

In speaking of this subject, I feel it is desirable to call the attention of the audience to the fact that it is believed that the Secretary of this Institute, Major Owens, was the first to make practical use of the principles involved, and he held the original patent in this country concerning this very useful feature of safe navigation.

This operation of pilot directing involves the laying of a cable in channels where it is proposed to be used, such as the main channels leading to our various large ports. It found extensive use during the war in laying cables through dangerous mine fields, and afforded a means of safely conducting ships through these dangerous localities in safety.

The radio piloting cable as recently demonstrated by the Navy Department in New York harbor, may be described as follows:

A rubber insulated cable having an internal conductor of seven strands, No. 16 copper wire, and an external armor of No. 12 galvanized steel wire, was laid from Fort Lafayette in the Narrows to a point approximately 1900 yards from the Ambrose Channel Light Vessel. This cable was laid exactly in the middle of the channel, the depth of which varies from 40 to 100 feet. The internal conductor of this cable is connected at the Light ship end of the cable to the armor and current is supplied to the cable by a 1-kw., 500-cycle alternator at Fort Lafayette.

The internal conductor of the vessel is connected through an automatic key and inductance to one terminal of the alternator, while the other terminal of the alternator is connected directly to the armor. The current as transmitted into this cable by means of the automatic key flows out through the inner conductor to the extreme end of the cable and then returns by way of the armor and also the surrounding salt water. The total length of this cable is 87,000 feet, while the impedance of the cable is 123 ohms. For best operating conditions a current flow of 3 amperes at 325 volts is supplied to this cable.

The equipment for receiving signals from this cable on board consists of two coils of wire placed on opposite sides of the ship approximately amidship and above the water line. These coils at the present time contain 400 turns of wire wound on a form four feet square. Leads from these coils are run to a double-pole, double-throw switch on the bridge of the vessel, by means of which electric energy as received from the cable can be transferred to a two-stage audio frequency amplifier. Connected to this amplifier are the regular Navy Standard Telephone Receivers. The action of the receiving apparatus is similar to ordinary electrical engineering wherein current flow is produced in a closed electrical loop when the loop is brought under the influence of a pulsating magnetic field. When the vessel is approximately directly over

the cable, the same electro motive force will be induced in each coil, therefore indicating in the telephone receivers on the head of the pilot an equal signal strength from each coil. Should the vessel move to the right or to the left of the cable, there will be a difference in the received signal strength as noted by the different coils, due to the fact that the coil nearest the cable will receive the maximum signal while the coil that is farthest away from the cable will receive the minimum signal.

During the demonstration test conducted during the week of October 4, 1920, it was found that readable signals were obtained from the cable when the destroyer *Semmes* was 1100 feet to the right or to the left of the cable, in this case the distance is approximately 50 feet outside of the channel buoys.

It was also found during these tests that very little experience was required for the average seafaring man to familiarize himself with this equipment and to safely pilot vessels through the Ambrose Channel, even when persons were blindfolded. Three seafaring men, two of which were local pilots and the other a captain of the Cunard Liner *Virgilia*, successfully piloted the destroyer *Semmes* through the Ambrose Channel at the speed of ten knots. These men had never seen this equipment before, but after one-half hour's instruction were able to take the control of the ship and relieve the captain of the duties of navigating the vessel. There were approximately 139 prominent people to witness these tests and of that number there was no person who found fault with this system, and upon being questioned were thoroughly in favor with the assertions made as to the future possibilities of this system. Before leaving the destroyer *Semmes* they thanked the Navy officials for having brought to their attention the possibilities of this new aid to navigation.

APPLICATION OF RADIO COMPASS TO DETERMINE PRESENCE OF THUNDERSTORMS AND FORECASTING THEIR PRESENCE AND APPROXIMATE LOCAL DIRECTION.

The radio telephone set has proven itself of immense value in detecting the approach of and recession of thunderstorms. With increasing static in a radio telephone set, an observer is able to determine a storm's approach, while decreasing static indicates the breaking up of the disturbance or its movement farther away from the station. Storms that were 50 to 150 miles away have

been detected in this way. On one occasion an observer heard static about 3.30 P.M., which increased until 6.00 P.M., and then decreased until 8.00 P.M., when the sky became clear. Upon translating code words received from the Weather Bureau, it was learned that a thunderstorm had occurred in a neighboring locality that exactly fitted the conditions observed in the static observations. An observer soon becomes accustomed to various static intensities and variations. Looking at distant lightning on a cloudy night, and at the same time noting the various grades of static, is the ideal way to get training with this device. By noting the time by stop watch between heavy growls of static and time thunder is heard, an observer can get an idea as to the distance of the storm from flashes that would ordinarily be hidden from view. This device is very useful for detecting storm static when hurricanes are in the Gulf of Mexico.

The following important facts have been noted, which are considered worthy of attention of all naval operators, and particularly aircraft operators:

1. Increasing local static denotes the approach of thunderstorms. If static is heavy the showers and squalls attending the storm will be heavy, and severe lightning may be expected. If the static is weak rains will be light to moderate, and without squalls;

2. Increasing, stationary, then decreasing static, denotes that disturbance is approaching, passing by, and moving away; in these cases the clouds may or may not show along the horizon as the storm passes;

3. The direction of the storm may be obtained by the radio compass;

4. It is thought that distant storm static may be detected by operators at radio compass stations, and the position of storms at sea obtained by interception of azimuth bearings given and storm's position charted frequently to obtain its force and future course, and give warning to interests involved.

5. It is probable that tropical hurricanes may be detected and movement shown through Caribbean Sea and Gulf of Mexico.

6. It may be difficult to get static from winter cyclonic storms and storms in the North Atlantic, on account of the absence of electrical disturbances attending them.

USE OF RADIO APPARATUS IN CONNECTION WITH WEATHER FORECASTS.

In order to use radio for detection of storms, and in a general way to give forecasts of the direction and proximity of storms, the following observations are given by which the presence of static in the receivers of radio apparatus can be used to advantage in weather forecasting.

Case A.—Reception from ordinary antenna, where no radio compass is installed.

Any unusual or sudden change in character or intensity of strays can be observed by radio operators and recorded in the log. A rapid rise in strays on short wave lengths usually indicates the approach of a storm, or at least a sudden change in the weather conditions. This does not mean that the usual increase in strays which comes after sunset in summer has any particular significance, unless the increase is abnormal and much longer than usual. When a storm is very close it is, in summertime, almost invariably preceded by a great increase in strays on short waves. The character of the strays gives some clew to the nature of the weather disturbance. A continuous succession of grinders seems usually to be followed by a general change in weather conditions, from fair or quiet, to unsettled and stormy. The storm centre may be at a considerable distance, but if there is a rapid increase in the whip-crack variety of strays, it is practically certain that a fairly violent electrical disturbance, which means a storm of considerable magnitude, is approaching.

Case B.—Observations at radio stations on ship or shore where radio compasses are installed.

In addition to the observations indicated in the preceding paragraph, the operator in charge of the direction finder is usually able to determine the line along which the storm is approaching, as the strays will be much weaker in certain positions when direction finder coil is turned than in others. In other words the strays will show a minimum, the same as a signal does, though not nearly so marked, as the strays do not come from one particular point, but from a general storm area. If the strays do not show themselves to be weaker in some directions than in others, it may be inferred, if they are exceptionally strong, that the unsettled weather conditions are pretty general and that no local violent storm is in progress. In the case of a local violent storm approaching from a distance, say inside of 50 miles, the whip-crack variety

of strays which will be sure to precede it will certainly show a pronounced favorite direction. It is usually possible to determine within 30° and sometimes closer the line along which a disturbance is approaching. If, for instance, the strays are at a minimum, with the pointer of the compass at 90°, they will also be at a minimum at 270°. The choice between these two directions, diametrically opposed, will have to be determined by general weather conditions, unless the operator is provided with a one-way compass. He cannot determine from which direction strays are coming, that can merely get the line. This information should be of considerable value, if carried out by experienced operators.

GENERAL METHODS OF SIGNALING BY RADIO AT SEA.

The general method of synchronous signaling is eliminated in cases where sounds or signals are made simultaneously in the air or underwater. Thus if a vessel, a lightship, for example, is so arranged that it will emit a sound in the air such as is caused by a steam whistle, and a sound under the water is emitted say by a stroke on a bell, the sounds will reach an observer at different times, depending upon the relative velocities of air and water. If this interval between the sounds can be noted by a stop watch, the distance from the signaling stations can be readily obtained. If a sound signal in the air is replaced by a radio signal, a simple means is at once found to obtain the required distance from source of sounds. Thus, if an arrangement is made so that a radio dot is sent out at intervals of about .6 of a second, a submarine bell stroke being sent at the same time, the latter lags the interval between two dots for about each half sea mile traveled. If the ship is five miles from the sending station, the sound lags five times the interval, and the bell comes in on the 10th dot, supposing the 1st radio dot is emitted .6 of a second later than the 1st bell stroke. In this case it is only necessary to count up the number of radio dots and count the number of half sea miles separating the ship from the signaling station. By interpolation it is quite possible to tell when the bell stroke falls somewhere between two consecutive radio dots, and an estimation to the ¼ sea mile is feasible.

The Fessenden oscillator has long been a rival to the undersea bell as a means of sending sound waves in water, and it seems highly probable that on large ships it will take the place of the

bell. As the result of an experiment, claims have been laid to: (1) Increased radius of audibility up to 30 miles or more; (2) Easy signaling over these distances of Morse code, by ordinary telegraph key; (3) Reception and emission of signals by one and the same apparatus, located in a ship or lowered overboard; (4) Determination of depth beneath the moving vessel by echo from the bottom; (5) Location of icebergs by reflected sound from submerged part of the berg.

Other uses of radio to warn mariners of danger into which they may be running, are provided by small radio telephone sets located at important points. Thus, by a phonographic arrangement connected with an automatic radio telephone set, constant words may be spoken by the set, which carries over a certain determined range, which is greater than the visible range. Thus, at Point Judith, an arrangement of this kind was made so that the intensity of the sound and radiation of the transmitter were so decided that ships equipped with the ordinary antenna would hear the signals the same approximate distance that light could be seen in clear weather. The automatic arrangement emits the name of the station every 5 seconds. When that is first heard the observer knows that he is about the same distance from the station that he would view the light in in clear weather. As the ship approaches the station, another automatic signal, which is continually being given out, but which is only heard at a reduced distance, gives a speech something like this: "You are getting closer! Keep off!" This indicates that the ship is too close to the sending station and must change her course to increase the distance. This signal also should only be heard at a certain distance, which the navigator knows. This instrument has been called the radio phone and it is intended to set up several of these radio phones at different stations on the Atlantic and Pacific coasts. These radio phones used in connection with a radio compass abroad ship, readily enable the navigator not only to obtain his bearing from the sound, but also his approximate distance.

Ships fitted with electric oscillators may readily communicate with one another by underwater signals in thick or foggy weather, when they cannot be seen by one another. Each ship may then signal to the other its course and speed, and each ship individually receiving this information can form a reliable estimate of the bearing of the others and the relative distances by the varying

intensity of signals, and thus more readily maneuver in order to avoid collisions.

DETERMINATION OF DEPTH OF WATER.

One of the most recent developments in the use of varying sound-signaling and listening devices installed on ships of the Navy, has been the development of a means of finding the depth of water under a ship without the use of any mechanical devices. It is believed that this was first noted in March, 1919, on board the U.S.S *Von Steuben,* while making her first trip from Hoboken to Brest after having been equipped with an electrical hydrophone. The discovery resulted from the fact that the propeller sounds of other vessels, and, in fact, of the *Von Steuben* herself, could not be heard in water over 1000 fathoms deep. This fact led to the conclusion that the only propeller sounds that affected hydrophones were those that suffered reflection from the sea bottom. Sounds from a source such as a propeller reach the hydrophone receiver, which may be installed near the bow, by three different paths, namely, from reflection from the surface of the water, directly through the water in a straight line, and from reflection from the bottom. If the distance from the source of sound, the propellers to the hydrophone, is relatively great with respect to the distance the propellers are beneath the surface, then two of the paths, directly through the water and reflection from the surface, are nearly equal. The reflection from the surface being from a rare to a dense medium, introduces a change of phase of one-half the wave length, and as a result, the sound which travels directly from the propellers to the hydrophone, and that which is reflected from the surface, will give almost complete interference at the receiver. The only sound heard then, will be that reflected from the bottom. Since the only propeller sounds heard by the hydrophone located at a distance and near the surface is the component reflected from the sea bottom, it follows that the depth of water can be determined from the angle which the reflected sound makes with a fixed line in a plane determined by the sound time and the reflected rate, provided the distance between the hydrophone and the source of sound is known. Conversely, the distance between the hydrophone and the sound source can be determined if the depth of water is known. This last is of great importance in determining the distance of other ships, by means of the hydro-

phone, provided depth of water is known. The depth of water may be calculated from the following simple formula:

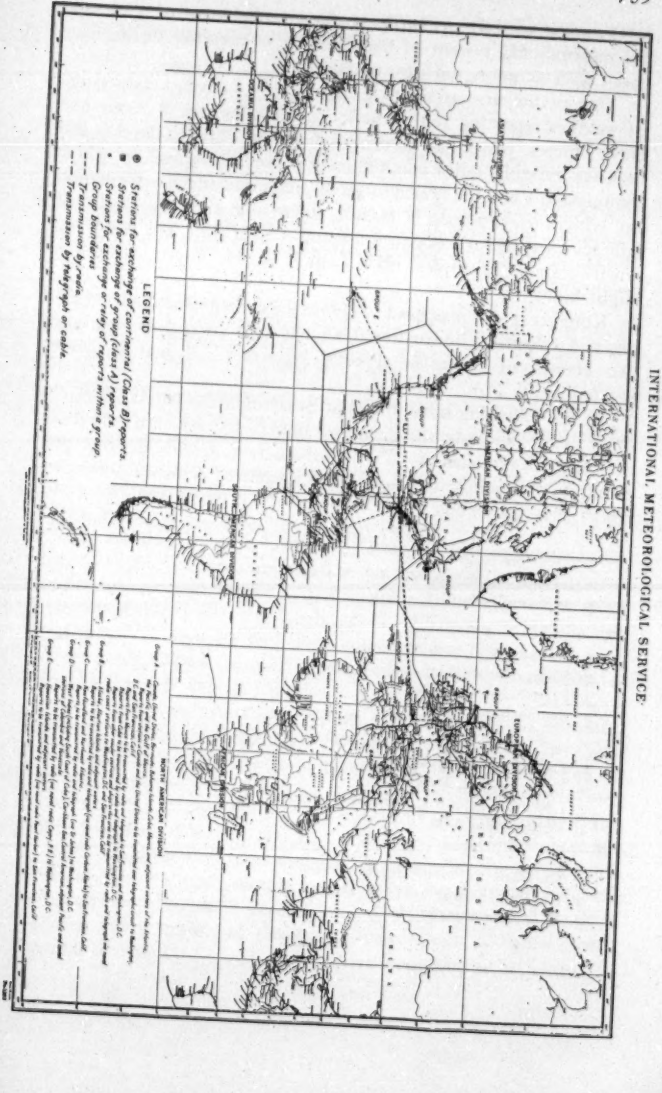
$$D, \text{ depth}, = C + L \tan \phi.$$

Where D represents depth, C is distance of sound producer below surface and $2L$ is distance between propeller and hydrophone. The angle ϕ 5 is referred to as sounding angle and is the supplement of angle theta, θ, which is the angle sound makes with ship's keel extended forward. Some errors are introduced in this by the character of the bottom, depending upon rapidity with which the depth of bottom changes and its slope, but, as an average, this method gives results which coincide very accurately with measured distances. It can readily be seen that if the depth is known the distance between the source of sound on one ship and a receiver on the other can be made the means of determining the distance between ships, which, in thick weather, is very desirable. This method of obtaining depth has been repeatedly checked with hand leads and general sounding machines in use at sea, and has been found to give very accurate results. It can be carried on at any speed, so it is shown that a ship fitted with a hydrophone can know at any time what is the depth of water under her, and furnishes ready means of keeping shipping out of dangerous waters. It will also readily be seen how the application of this principle of sound reflection can be used to determine the presence of any submerged object.

INTERNATIONAL METEOROLOGICAL REPORTS.

Many countries make provision for some sort of meteorological report to be broadcasted to sea by radio for the benefit of shipping in the immediate vicinity, and nearly every country has developed some sort of meteorological reports for the purpose of forecasting local weather. The United States has a highly developed service, both for local forecasting and for transmitting reports to ships and aircraft, by radio, and which has been previously described.

For a long time there have been serious attempts made to create an international weather reporting service, based on similar lines of procedure, using a common code that could be used alike for ships and aircraft. The development of the aircraft service and particularly that part which involves international flying,


INTERNATIONAL METEOROLOGICAL SERVICE
NORTH AMERICAN DIVISION
LEGEND
Stations for exchange of continental (Class B) reports
Stations for exchange of group (Class A) reports
Stations for exchange of relay of reports within a group
Group boundaries
Transmission by radio
Transmission by telegraph or cable

rests almost entirely primarily on the establishment of a successful international system of transmission of weather intelligence, based on a common, uniform practice.

One of the first attempts to produce an international system of weather reporting fell to the lot of a conference of Army and Navy officers, which had several meetings in Paris to develop and improve existing radio communication procedure, and on which commission I had the honor to serve. Without much information on which to proceed, it is not surprising that the body of military men did not produce a completed project, but it did lay down certain principles upon which others more competent might build.

Roughly it was proposed to divide the principal countries needing and collecting international reports into several groups, and two classes of collective reports, known as *A* and *B*, were decided upon.

In the following table it was proposed that the letters *A*, *B*, *C*, *D*, *E* and *F*, indicate the grand groupings for which a collective report, *B*, is established. The numbers 1, 2, 3, etc., indicate the countries or groups of countries, for each of which a collective report *A* is drawn up:

GROUP A.

1. Great Britain.
2. Iceland, Denmark, Sweden, Norway.
3. Archangel, Esthinia, Finland.

GROUP B.

1. Holland, Belgium, France.
2. Spain, Portugal.
3. French North Africa.
4. Switzerland.

GROUP C.

1. Italy, Malta, Servia.
2. Egypt, Libya, Palestine.
3. Greece, Roumania, Constantinople.
4. Poland, Bohemia.

GROUP D.

1. Germany (or the German States).
2. Austria (or the Austrian States), Bulgaria.
3. European Russia.

GROUP E.

Africa (to be considered later).

GROUP F.
North America (to be considered later).

The countries charged with the preparation and the transmission of the collective reports *B* are the following:

Norway for Group A.
France for Group B.
Italy for Group C.
Germany for Group D.

The stations, the ranges of which are at least 3000 kilometres, which are to be utilized for the transmission of reports *B*, may be considered to be as follows:

Stavanger for Group A.
Lyons for Group B.
Rome for Group C.
Nauen for Group D.

The stations which will be utilized for the transmission of reports *A* will be determined later, after an agreement with the countries interested.

The reports *B* will be transmitted simultaneously three hours after the observations, *i.e.*, at the following hours: 0400, 1000, 1600, 2200.

As an illustration in Group *A*, Great Britain makes up a collective report *A*, and transmits it by radio to the high power radio station at Stavanger, Norway, and similarly the other countries numbered 2 and 3 in Group *A*. The Stavanger station then transmits, for international use, a collective report *B*.

It is noted that Group *E* is marked to be considered later, as well as Group *F*, North America.

With this information, various United States Government officials took up the subject for further development. This Committee concluded that the proposed scheme above outlined did not entirely meet the requirements for a world meteorological service, and in order to promote the realization of this highly desirable objective, recommended that each continent, adjacent waters and islands, be organized as a division as shown on the screen, that one country in each continental division be charged with the preparation of class *B* reports, and then transmission by high power radio station at designated fixed lines, to other continental divisions.

In accordance with this recommendation, the following continental divisions were suggested:

1. European
2. African.
3. Asiatic.
4. Oceanic.
5. North American.
6. South American.

The following organization for the transmission of Class *A* reports for the North American Division, was recommended:

GROUP A.

Canada, United States, Bermuda, Bahama Islands, Cuba, Mexico, and adjacent waters of the Atlantic, the Pacific and the Gulf of Mexico.

Reports from stations in Canada and the United States to be transmitted over telegraphic circuit to Washington, D. C., and San Francisco, Calif.

Reports from Mexico to be transmitted by radio and telegraph to San Francisco and Washington, D. C.

Reports from Cuba to be transmitted by radio and telegraph to Washington, D. C.

Reports from other insular stations and ships in this area to be transmitted by radio and telegraph via naval radio coast stations to Washington, D. C., and San Francisco, Calif.

GROUP B.

Alaska and Aleutian Islands, and adjacent waters.

Reports to be transmitted by radio and telegraph (via naval radio Cordova, Alaska) to San Francisco, Calif.

GROUP C.

Newfoundland and Northwest Atlantic.

Reports to be transmitted by radio and telegraph (via St. Johns) to Washington, D. C.

GROUP D.

West Indies (including South Coast of Cuba), Caribbean Sea, Central American, adjacent Pacific, and coastal stations of Colombia and Venezuela.

Reports to be transmitted by radio (via naval radio Cayey, P. R.) to Washington, D. C.

GROUP E.

Hawaiian Islands and adjacent waters.

Reports to be transmitted by radio (via naval radio Pearl Harbor) to San Francisco, Calif.

It is recommended that the United States be designated as the administration to prepare Class "B" reports for the North American Division and to transmit them via Annapolis and San Diego.

Each of these groups would prepare a collective *A* Group and transmit by appropriate radio stations or land wire stations to the next group, so that each group would have the benefit of the information from other groups in making their more or less local forecasts. Eventually all the Group *A* collective reports would reach Washington, where they would be used for general forecasting purposes, and would then be transmitted by the Annapolis high power radio station for international use, in the form of a collective *B* report. Similarly, one high power station in each of the other continental divisions would receive *A* reports from their proper division and transmit a collective *B* report which would be received in all the other countries.

All of these collective *A* reports and collective *B* reports would be available at their collecting centres for local use, and transmitted to sea by local radio stations either on the coast or in the interior, for use of ships and aircraft.

The report of the American Committee is now being considered by the delegates to the Preliminary Conference on Communications, now meeting in Washington, and it is confidently hoped and expected that the above or a similar plan will be authorized and soon put into practice, when the whole world will have means by which better local and general forecasts of weather may be made, based on world-wide conditions.

Perhaps what I have to say now is not directly connected with the application of radio as applied to navigational problems, but indirectly finds some connection in case all available radio applications fail, and I have reference to another form of communication, which I wish to lightly touch upon, and that is the use of pigeons.

During the last ten months of the World War, U. S. Naval pigeons delivered 219 messages from seaplanes forced to land at sea. These planes were without any other means of communication, and credit must be given the pigeons for the saving of both men and machines. The most thrilling experience of any of our aviators is that credited to Ensign E. A. Stone, U.S.N.R.F., who, with Sub-Lieutenant Eric Moore of the Royal Naval Air Force, clung for eighty hours, without food or drink, to the underside of a seaplane pontoon. The duty of the above officers was convoying

patrol, and after having met their ship coming from the westward, they sighted a periscope ahead and started in pursuit. They unfortunately lost their course in a slight fog, and at 11.30 A.M. were forced to land on the surface in a rough sea, their engine completely dead. Two pigeons were aboard, and these were

PART I.

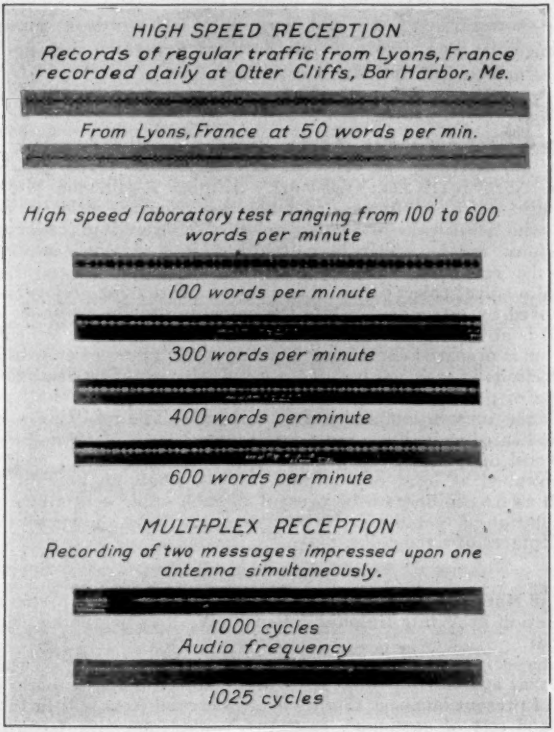
TRANSATLANTIC – RECEPTION
Records of regular traffic received at Otter Cliff Naval Radio Station – Bar Harbor, Me.
from Lyons, France
from Carnarvon, Eng.
from Nauen, Germany
RECORDS OF SIGNALS FROM U.S. STATIONS
from New Brunswick, N.J.
from Tuckerton, N.J.
from Arlington, Va.

Radio signals recorded by The General Electric Visual and Photographic Recorder, invented by Mr. C. A. Hoxie.

released at fifteen-minute intervals. The first pigeon arrived in Dunkirk with a message stating the whereabouts of the aviators and that their ship was sinking. Every available seaplane on the station was sent out in search; and although some of them flew as close as 800 feet from the wreckage and were easily discernible by the men on the water, eighty hours had elapsed before the

aviators were rescued. Lieutenant Moore lost six of his toes from gangrene, finally dying in the hospital. Ensign Stone recovered, and until recently was stationed at the U. S. Naval Air

PART II.


HIGH SPEED RECEPTION
Records of regular traffic from Lyons, France recorded daily at Otter Cliffs, Bar Harbor, Me.
From Lyons, France at 50 words per min.
High speed laboratory test ranging from 100 to 600 words per minute
100 words per minute
300 words per minute
400 words per minute
600 words per minute
MULTIPLEX RECEPTION
Recording of two messages impressed upon one antenna simultaneously.
1000 cycles
Audio frequency
1025 cycles

Radio signals recorded by The General Electric Visual and Photographic Recorder, invented by Mr. C. A. Hoxie.

Station, Anacostia, D. C. Many instances have occurred where pigeons operating on this side of the water have been instrumental in delivering messages requesting spare parts to be sent disabled

planes, and one pigeon at Cape May is credited with the rescue of one of our pilots off the Jersey coast last winter.

For those who may be interested in the modern development of the radio art, the accompanying diagrams of recorded signals show high-speed signaling by radio, recorded photographically. These show a transmission and reception of 600 words per minute in laboratory tests, and it is fully expected that some such figure may be approached in modern everyday practice.

Reagent for Cobalt.—A new reagent for the detection of cobalt is described by H. S. VAN KLOOSTER (*Journ. Am. Chem. Soc.*, 1921, xliii, 746–749). Nitroso R-salt, the nitroso derivative of 2, 3, 6 beta naphthol disulphonate, yields a red color with cobalt salts in aqueous solution. Silver, lead, cadmium, and other metals which have colorless ions do not interfere with the reaction. Salts of iron, nickel, chromium, and copper also give colors with the reagent, but these colors are destroyed by nitric acid, while the color due to the presence of cobalt is not destroyed. In order to test for cobalt, an aqueous solution is prepared containing from 1.5 to 2.0 grams of anhydrous metallic salts in each 100 c.c. To 2 c.c. of this solution are added 1 gram of powdered sodium acetate and 2 c.c. of a one-half per cent. aqueous solution of the nitroso R-salt. The resulting solution is heated to boiling over a small flame; 1 c.c. of concentrated nitric acid of specific gravity 1.4 is gradually added; and boiling is continued at least one minute. If as small an amount of cobalt as 0.03 millegram be present in each cubic centimetre of the solution of metallic salts, its presence will be shown by the development of a red color.

J. S. H.

The National Fertilizer Association will hold its 28th annual convention at White Sulphur Springs, W. Va., beginning June 20, 1921.

The program will include addresses and discussions on subjects that are of vital interest to the fertilizer manufacturer, in view of present business conditions. These subjects will include costs and cost of accounting systems, chemical and manufacturing problems, sales methods, labor and transportation problems, etc.

The Southern Fertilizer Association, the Soil Improvement Committee of the National Fertilizer Association and the Soil Improvement Committee of the Southern Fertilizer Association will hold meetings during the time of the Convention.

LEONARDO DA VINCI—NATURAL PHILOSOPHER AND ENGINEER.*

BY

JOHN W. LIEB, M.E.

Vice President, the New York Edison Company. Member of the Institute.

THE epoch of human progress in which Leonardo da Vinci lived encompasses the latter half of the fifteenth and the first half of the sixteenth century, known as the period of the Italian Renaissance.

This is the period known in history as the Revival of Learning with its new conceptions of philosophy and religion; its dedication to new types in the arts; its casting aside of astrology, alchemy and the black arts for the natural sciences; its manifold inventions and discoveries; and its changed political systems.

In a broad sense the Renaissance signified a rescue from oblivion of the classical works of Greece and Rome in their influence on science, literature and the arts, a return to nature and the realities of life, and the evolution of mankind toward individual liberty as a reaction against medieval feudalism and asceticism.

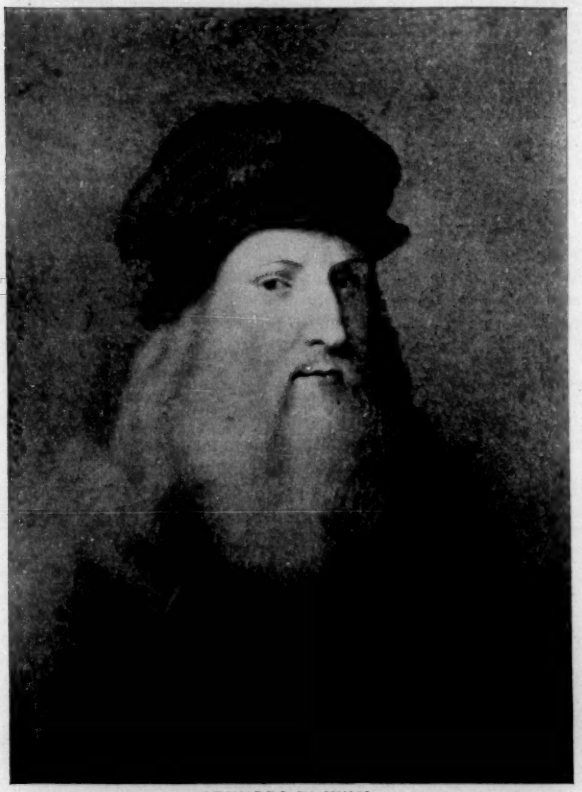
While the Renaissance typified a return to nature and the restoring of classical models, it also represented a distinct progression beyond, as indicated by Prof. J. H. Robinson in his essay "The Mind in the Making":

> "Greek civilization was founded on slavery and a fixed condition of the industrial arts. The Philosopher and scholar was estopped from fumbling with those every-day processes that were associated with the mean life of the slave and servant. Consequently there was no one to devise the practical apparatus by which alone profound and ever-increasing knowledge of natural operations was possible. The mechanical inventiveness of the Greeks was slight, and hence they never came upon the lens; they had no microscope to reveal the minute, no telescope to attract the remote; they never devised a mechanical timepiece, a thermometer or a barometer, to say nothing of cameras and spectroscopes. Archimedes, it is reported, disdained to make any record of his ingenious devices, for they were unworthy the noble profession of a Philosopher."

In this period of awakening and release from the tyranny of precedence and authority we find that many of the courts of

* Presented at the Annual Meeting of the Institute held Wednesday, January 19, 1921.

Europe, Imperial, Regal and Ducal with the consolidation of territories and the increase in wealth began to show outward splendor



LEONARDO DA VINCI
Portrait. Gallery Uffizi, Florence.

and luxury, their rulers becoming liberal patrons of the arts, and they attracted to their festivities and tournaments the flower of chivalry and the popular idols in art, music, and poetry.

Under the powerful protection and patronage of the illustrious Houses of Medici and the Sforza, art in its various manifestations attained a brilliancy and appreciation which made artists and poets most sought after in all the Ducal Courts, and we have ample testimony of its popular appreciation in the enthusiastic and laudatory testimony of contemporary prose and poetry.

It was in Italy that the glories of the Renaissance had their typical manifestation, and the splendor of the Ducal Courts, aided by the wealth of Italian Patricians and merchant princes, attracted to her all the learning of the times. The Universities of Bologna, Padua and Salerno were famous during the middle ages for the study of law, physics and medicine, and during the fifteenth and sixteenth centuries the first two still enjoyed world-wide fame. The Medieval curriculum, however, offered no definite place for the new knowledge developed by the revival of learning, the search after truth, and the unveiling of the secrets of nature, which had no recognized chairs for their exposition.

In the early Renaissance, chairs in the universities were founded under the title of Rhetoric and learned men expounded orally, to students from every nation in Europe, their accumulated knowledge of antiquity, a confused mass of Greek, Roman and Arabic erudition, including under this subject history and metaphysics, law and science, civic institutions and the art of war, poetry and oratory, religious ritual and Philology—all going to form the heterogeneous subject matter classed under the scholastic term "Rhetoric."

It was in the very midst of this interesting period that Leonardo da Vinci was born in 1452 in the village of Vinci near Florence, Italy, as the natural son of Piero da Vinci, a notary or councillor of the seignory of Florence, and Caterina, a woman of the peasant class.

The year of his birth Leonardo's father married a young woman of his own social level, and his mother married a peasant farmer and we lose all further track of her. Leonardo's father married three times and had eleven children, Leonardo having reached the age of twenty on the birth of the first legitimate child.

As a young man Leonardo became interested in music and according to Vasari, the gossipy biographer of that time, "He played on the lyre, singing and improvising devinely." He became interested in making sketches and plaster reliefs, and when

his father showed some of these drawings to the great Florentine Master Verrochio, he was accepted as an apprentice in that master's art shop or "bottega."

His master, like most of the Renaissance Craftsmen, was a gold and silver smith and a moulder in bronze as well as a sculptor and painter, so that his pupils acquired knowledge and practice in every branch of pictoral and plastic art. In addition Leonardo became interested in mathematics, mechanics and the making of experiments. As a mere youth he had acquired a life-

The Lord's Supper. Present condition. S. Maria della Grazia, Milan.

long habit of jotting down, in rough sketches, scrawls and hasty notes, what he saw, always carrying a note-book with him. These later notes bear dates beginning with his thirty-seventh year, and he continued to compile data and material for his manuscripts without serious interruption during the succeeding thirty years.

He left Florence about 1480 and is believed to have travelled throughout Italy during the next few years. About 1484 he was invited by Duke Ludovico il Moro to come to Milan, and for the next fifteen years was attached to the Ducal Court and took a conspicuous part in its activities, acting as Director of Pageantry in planning and organizing court festivities, making improvements in the Ducal Castles and estates, constructing canal and irrigation works in Lombardy and executing important work as painter and

sculptor. On the fall of the Ducal House of the Sforza, Leonardo left Milan, spending some time in Venice, then entering the service of Cesare Borgia as Military Engineer, and later returning to Florence where much of his work in art was done.

In 1508 he returned to Milan and in the following years he spent much of his time in investigation, experiment and research, delving into almost every realm of nature, planning all kinds of mechanism and machinery and investigating the laws of operation of natural and physical phenomena.

In 1515 he accompanied Francis the First to France as Court Painter and died in 1519 at the age of sixty-nine, at the Manor House of Cloux, Amboise, which the King had assigned to him as a residence. His was a most engaging personality, a brilliant conversationalist, musician and extemporizer, a fine presence and noble bearing, physically strong and of athletic build. He was every inch a courtier and possessed many of the graces required of a court favorite.

Such is a brief summary of Leonardo's life.

At the outset it should be stated, frankly, that it is quite impossible within the time that can be accorded to one address to give more than a mere outline of the life work of this extraordinary genius, even though we endeavor to confine our consideration to his activities in the realms of philosophy and engineering.

THE MANUSCRIPTS.

Any study of Leonardo must necessarily concern itself primarily with a consideration of his manuscripts, for it is through these rather than through any contemporary chronicle or products of his genius that he reveals himself to us.

Just how many manuscript volumes he left to posterity is not accurately known, and their arrangement and grouping into subject matter is in inextricable confusion. We know that altogether over 5300 sheets of his note-books have been found, covered with notes and sketches on one or both sides, the sheets varying in size from 4″ to 12″ long and from 3″ to 9″ wide.

In his will he left all of his books, sketches and paintings to Francesco Melzi, his pupil and friend, who removed them to the family seat at Vaprio near Milan, where they were carefully preserved for a time, but on Melzi's death in 1570 became widely scattered.

Three volumes including 1222 sheets have been brought together into one volume known as the Codice Atlantico, now in the Ambrosian Library, Milan. Twelve other volumes, comprising some 2200 sheets, are now in the library of the Institute de France, Paris; 596 sheets are in the Forster Library, S. Kensington

Sketches for equestrian monuments.

Museum, London; 566 sheets in the Royal Library, Windsor Castle; 566 sheets in the British Museum, London, and the rest distributed, some at Holkham Hall and at Milan, Rome, Turin, Florence, Venice, etc.

The notes, with comparatively few exceptions, are written backhand, in oriental style, *i.e.*, from right to left, "mirror-writing," in an archaic style of Italian with a tendency to group the letters phonetically. Some of the sentences are chopped off in the middle

and translation is further complicated by the use of archaic phrases, colloquialisms, abbreviations, absence of punctuation, etc.

The writing is executed in somewhat Byzantine characters and, to the expert, the reading can best be accomplished with the aid of a mirror.

We find on the very same sheet of these notes, in utter confusion of arrangement, an architectural plan, a sketch of a human figure or face—often a grotesque, a sketch of a leaf, plant or flower, a study of a geometric figure or drawing, or a machine, a calculation of cost or power required, all intermingled on the same page and having no relation whatever to one another.

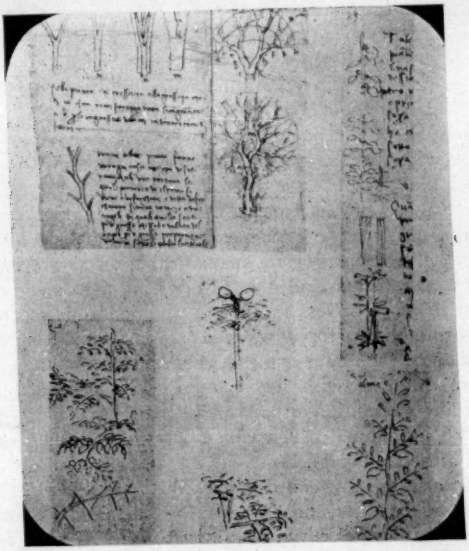
Nearly all of the manuscripts have now been reproduced in facsimile with literal reproductions of the text, with transcriptions into modern Italian and usually also with a translation into French, English or German. The Codice Atlantico is available in a very satisfactory Italian edition, the manuscripts in the Windsor Library treating of anatomical subjects are reproduced in a recent excellent Norwegian edition, and the other notes have appeared in more or less satisfactory editions due to the use of primitive photo-lithographic processes. No complete edition, however, exists of the manuscripts in the Windsor Library, and students are awaiting with much interest the promised bringing together in one edition of all of Leonardo's manuscripts in a "Corpus Vincianum," which will supply to students considerable material hitherto unpublished.

Several series of related notes, distributed throughout the manuscripts, have been brought together, arranging them as it is believed was intended in the form of treatises. These comprise a most complete and remarkable text-book called "The Treatise on Painting," which has had numerous editions in several languages, a treatise "On the Motion and Measurement of Water," and a booklet on the "Flight of Birds."

It appears to have been Leonardo's intention to compile a number of treatises which should embody the results of his investigations, for he says:

> "This will be a collection without order made up of many sheets which I have copied here, hoping afterwards to arrange them in order in their proper places according to the subjects of which they treat." Ms BM 263 Ar (Windsor)

In addition to the treatises mentioned above, he speaks of writing a book "About the Human Figure"; in another place he refers to a book on "Light and Shade," and in another on "Movement and Weight," and Lomazzo refers to a treatise by Leonardo on the anatomy of the horse. One of the few contemporary references to these manuscripts occurs in the diary of Antonio de



Botanical sketches. Arrangement of leaves and limbs of trees.

Biatis, secretary to the Cardinal of Aragon, who visited Leonardo at Amboise in 1517. He says:

"This gentleman (Leonardo) has written of anatomy with such a wealth of detail, illustrating by his art both limbs and muscles, nerves, veins and ligaments of the inward parts, and of all that may be demonstrated in the bodies of men and of women, in a way that has never before been equalled by any one else; we have seen with our own eyes, and he has also told us that he has dissected more than thirty bodies of men and women of all different ages. He has also treated of the nature of water, of various machines and of other matters which he has dealt with in an endless number of volumes; and all in the common tongue, which when they are made public, will be profitable and very delectable."

Leonardo was a keen searcher after the cause and reasons for the things he saw about him, and his greatest delight was in discovering the fundamental laws underlying natural and physical phenomena.

He was continuously endeavoring to express the facts and manifestations of nature in terms of what he called a "regola"—a general rule or law. His notes are full of such expressions as these: Try this; observe that; note the effects of this; go tomorrow and ask Maestro Antonio how mortars are placed on bastions by day or by night. He says: "I remind you that you confirm your statements and your conclusions through examples and not assertions, which would be too easy. You should say: Proven by experiment!" Here we have revealed an indomitable spirit whose restless energy and depth of thought, whose desire to know how and why and insatiable yearning to understand nature in all her wonderful manifestations is unique in the history of mankind, for there is hardly a department of human knowledge which he has not touched upon and to which his notes do not make some pertinent reference.

Several questions arise which we should endeavor to answer at this time.

Why did Leonardo usually write from right to left, "mirror-writing," as it is called?

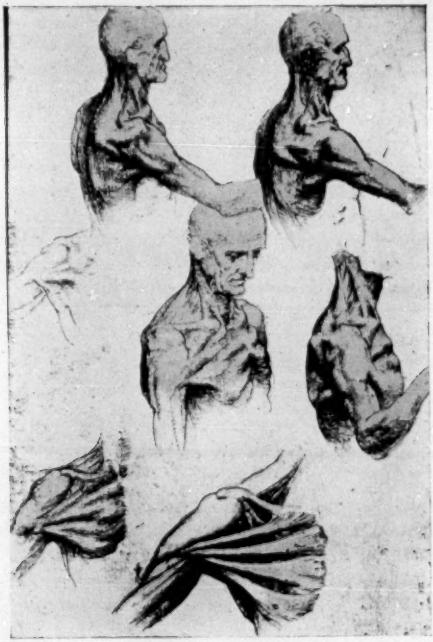
Volumes have been written by students of Vinciana offering many varied explanations for this mirror-writing of Leonardo, but Prof. Arthur L. Beeley in a recent monograph entitled "An Experimental Study of Left-handedness" has shown conclusively in his exhaustive investigation, covering a school population of over 100,000 pupils, that there is one "mirror-writer" in every group of about 2500 children of elementary school age, and he concludes from his careful study of left-handed children that "mirror-writing" is by far the easier style of writing for all sinistrals, and Leonardo was most certainly left-handed.

Another question arises, as to the literary attainments of Leonardo, and as to his familiarity with classical and contemporary authors and writers on natural science and philosophy.

In one of his notes in the Codice Atlantico, Ms C A Fol 119r, he says:

"I am fully aware that the fact of my not being a man of letters may cause certain arrogant persons to think that they may with reason censure me,

alleging that I am a man ignorant of book learning. Foolish talk! Do they not know that I might retort by saying, as did Marius, to the Roman Patricians: 'They who themselves go about adorned in the labor of others will not permit me my own.' They will say that because of my lack of book learning I cannot properly express what I desire to treat of. Do they not know that my subjects require for their exposition experience rather than the words of others? And



Muscles of the chest and neck.

since experience has been the mistress of whoever has written well, I take her as my mistress, and to her in all points make my appeal."

And in this interesting note in which he appears as the original chastiser of the "nature fakir":

"I know well that because I am illiterate certain presumptuous ones seem to think it proper to criticise me by alleging that I am without literary knowledge.

Good writing is based on good knowledge of nature; and as greater consideration should be given to cause than effect, so I would give greater praise to a good naturalist without literary knowledge, than to a good literary man without knowledge of nature." Ms CA Fol 76r

But, was Leonardo illiterate? Not at all! and we should answer this question now before we come to consider his work as a philosopher. We find him to have been familiar with many classical and contemporary authors, although, as Richter says of him:

"It was evidently no part of his ambition to be deeply read, and he more than once expressly states that he did not recognize the authority of the Ancients on scientific questions, which in his day was held paramount. Archimedes is the sole exception, and Leonardo frankly owns his admiration for the illustrious Greek to whose genius his own was so much akin."

Nevertheless, he frequently quotes from Aristotle, Anaxagoras, Pliny, Hippocrates, Vitruvius, Avicenna, etc.

Throughout his notes we find references to books which he wishes to consult or obtain and where they may be found, as, for instance: "Take the book by Vitolone, on the measurements of the public buildings"; "an algebra which the Mariani have, written by their father"; "get Messer Fazio to show you the book on proportion"; "the measurement of the sun, promised me by Maestro Giovanni, the Frenchman"; "get the Friar of Brera to show you the book 'De Ponderibus'"; "The Archimedes belonging to the Bishop of Padua"; "On the increase of the Nile, a small book by Aristotle"; "the heirs of Maestro Giovanni Ghiringallo have the works of Pelacano," etc.

Before leaving the manuscripts, while we are not here concerned with his purely literary activities, we should refer to several of the interesting letters they contain, as they throw considerable light on his personality and his intensely human sympathies.

In a letter written about 1480 to Duke Ludovico Il Moro offering his services as Military Engineer, he says:

"Having, My Most Illustrious Lord, seen and now sufficiently considered the proofs of those who consider themselves masters and designers of instruments of war, and that the design and operation of said instruments is not different from those in common use, I will endeavor without injury to anyone to make myself understood by your Excellency, making known my own secrets, and offering thereafter at your pleasure, and at the proper time, to put into effect all those things which for brevity are in part noted below—and many more, according to the exigencies of the different cases.

Anatomy of the throat, muscles of the leg, etc.

I can construct bridges very light and strong, and capable of easy transportation, and with them pursue or on occasion flee from the enemy, and still others safe and capable of resisting fire and attack, and easy and convenient to

place and remove; and methods of burning and destroying those of the enemy.

I know how, in a place under siege, to remove the water from the moats and make infinite bridges, trellis work, ladders and other instruments suitable to the said purposes.

Also, if on account of the height of the ditches, or of the strength of the position and the situation, it is impossible in the siege to make use of bombardment, I have means of destroying every fortress or other fortification if it is not built on stone.

I have also means of making cannon easy and convenient to carry, and with them throw out stones similar to a tempest; and with the smoke from them cause great fear to the enemy, to his grave damage and confusion.

And if it should happen at sea, I have the means of constructing many instruments capable of offense and defense, and vessels which will offer resistance to the attack of the largest cannon, powder and fumes.

Also, I have means by tunnels and secret and tortuous passages, made without any noise, to reach a certain and designated point; even if it is necessary to pass under ditches or some river.

Also, I will make covered wagons, secure and indestructible, which entering with their artillery among the enemy will break up the largest body of armed men. And behind these can follow infantry unharmed and without any opposition.

Also, if the necessity occurs, I will make cannon, mortars and field-pieces of beautiful and useful shapes, different from those in common use.

Where cannon cannot be used, I will contrive mangonels, dart throwers and machines for throwing fire, and other instruments of admirable efficiency and not in common use; and in short, according as the case may be, I will contrive various and infinite apparatus for offense and defense.

In times of peace I believe that I can give satisfaction equal to any other in architecture, in designing public and private edifices, and in conducting water from one place to another.

Also, I can undertake sculpture in marble, in bronze or in terra cotta; similarly in painting, that which it is possible to do I can do as well as any other, whoever it may be.

Furthermore, it will be possible to start work on the bronze horse, which will be to the immortal glory and eternal honor of the happy memory of your father, My Lord, and of the illustrious House of Sforza.

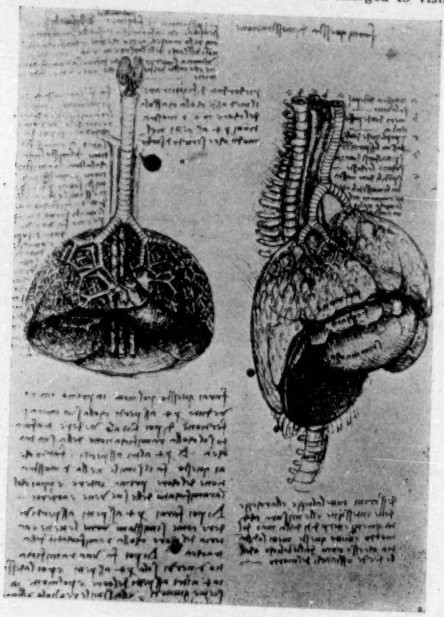
And if to anyone the above mentioned things seem impossible or impracticable, I offer myself in readiness to make a trial of them in your park or in such place as may please your Excellency; to whom, as humbly as I possibly can, I commend myself." Ms CA Fol 391r

A most self-laudatory letter, it is true, but Leonardo seems to have demonstrated his ability to produce results in all these matters.

At Pavia, August 18, 1502, where Cesare Borgia had gone to render homage to Louis XII, is dated a letter-commission from the former, conferring on Leonardo—his private architect and

engineer, the commission of Inspector General of the Duchy of Urbino:

"To all our Lieutenants, Castellans, Captains and Condottieri, officers and subjects, who receive this notice, it is commanded and ordered, in favor of our very excellent and favorite private architect and Engineer General Leonardo Vinci, bearer of these letters present, whom we have charged to visit the places



Lungs and thorax.

and the fortresses of our estates, in order to have them put back into condition according to the exigencies and in his own decision, to guarantee him freedom of movement, all exemption from payment of public taxes; to give a friendly welcome to him and his companies; to help him in visiting, measuring and estimating the localities as much as he pleases; and to this end to place at his disposal the men he requires; to give him all aid and assistance that he requires and finally carry out our wish, that for the work to be done in our domains all engineers shall confer with him and conform to his orders." Original in archives of Duke Melzi, Milan.

We should not leave further consideration of the manuscripts without referring to the prophesies, fables, beastiaries, and rebuses in which the notes abound.

A few aphorisms may be quoted:

"Ask counsel of him who governs himself well" Ms H III Fol 118v

"When fortune comes seize her with a firm hand and in front, I counsel you, for behind she is bald" Ms C A Fol 289v

"As a day well spent gives cheerful sleep, so a life well spent gives cheerful death" Ms Tr Fol 27r

"Nature never breaks her own law" Ms E Fol 43v

"To devise is the work of the Master, to execute the act of the servant" Ms CA 109va

"In speculation about perpetual motion, how many vain chimeras have you created in that quest? Go and take your place with the seekers after gold (Alchemists)" Ms SKM II, Fol 67r

"Although human ingenuity makes a variety of inventions answering by different means to the same end, it will never devise an invention more beautiful, more simple or more direct than does nature because in her inventions nothing is lacking and nothing is superfluous" Ms WAN IV Fol 184r

"Science is the captain, practice the soldiers" Ms J Fol 130r

"Avoid studies of which the result dies with the maker" Ms SKM III 36b

"Practice should always be founded on sound theory" Ms G Fol 8r

"As is the mould, so will be the casting." R 21, H, 52b and Ms H Fol 100 [43r] v

His fables cover such subjects as: "The Flame and the Candle," "The Elm and the Fig Tree," "The Walnut Tree and the Tower," etc.

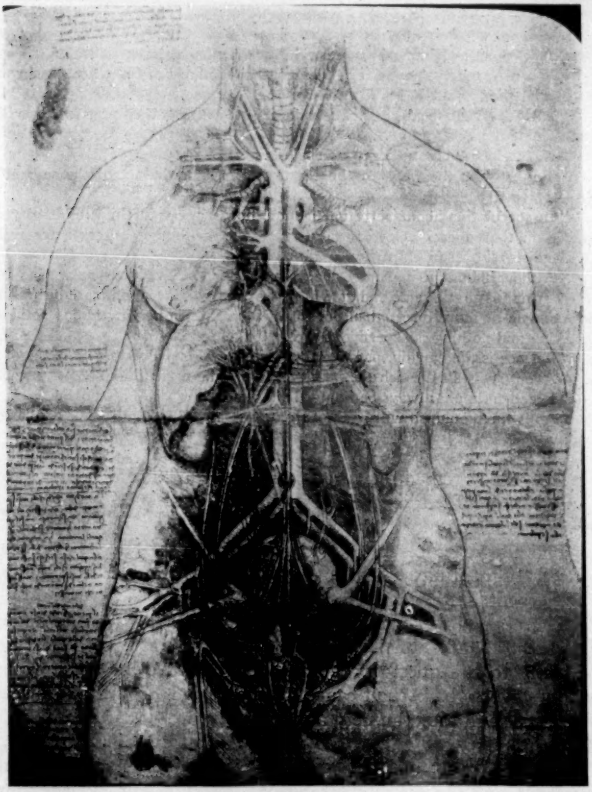
The allegories refer to such subjects as: Cruelty, Prudence, Justice, Ingratitude, etc., and among beastiaries: The Dolphin, The Serpent, The Dragon, The Bat, etc.

There are also some curious writings called prophesies about the earth, about animals, plants, etc., as, for instance, referring evidently to the quest for gold: "That shall come forth from hollow caves which shall cause all the natives to toil and sweat with great agitation, anxiety and labor, in order to gain its aid." Ms C A Fol 37v

Having briefly outlined in the foregoing the environment of Leonardo and the many sided quality of his genius, we are now prepared to examine his manuscripts and notes in some detail with special reference to his researches, thoughts and activities as a Natural Philosopher and Engineer.

In order to attempt to do a measure of justice to these phases

of the general subject, it becomes necessary for us to dismiss, in just a few words, consideration of those accomplishments for



Viscera of human body.

which he has won immortal fame as among the world's greatest artists long before his unique achievements in science and engineering had become generally known and appreciated.

PAINTING AND SCULPTURE.

We have already referred to that remarkable production which forms the basis of his applied art, the Treatise on Painting, which is a complete text-book in itself, so modern in its conception and useful in its suggestions that a modern translation is being used to-day as a text-book in French art schools.

Although evidently a mosaic and compilation from his notes, probably brought together for use in teaching in the Accademia Vinciana which he founded in Milan, it is of itself a monument to his genius as an artist and scientific investigator. In it he sums up tritely and profoundly the painter's purpose: "A good painter has two chief objects, to paint man and the intention of his soul. The former is easy, the latter hard, because he has to represent it by the attitudes and movements of the limbs."

A glance at the sub-heads into which the book is divided will show the breadth of the treatment:

1. The nature of paintings, poetry, music and sculpture.
2. Precepts for the painter.
3. Of positions and movements of the human figure.
4. Of drapery.
5. Light, shade and perspective.
6. Of trees and foliage.
7. Of clouds.
8. Of the horizon.

How completely modern is the treatment will appear strikingly from a few quotations:

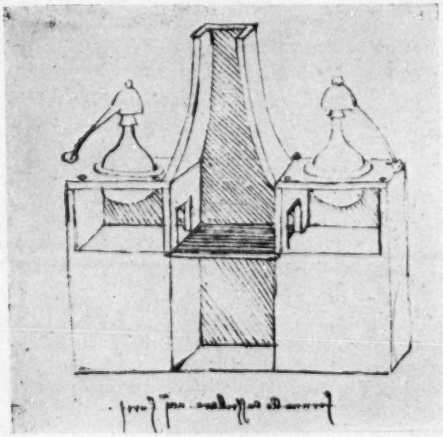
"These rules (for painters) secure to you a sound and liberal judgment; because good judgment is born of good understanding, and good understanding is the result of reasoning based on good rules and good rules are children of good experience, the common mother of all sciences and arts. Solmi, Frammenti Letterari e Filosofici, p. 79.

"The first picture consisted merely in a line which surrounded the shadow cast by the sun upon a wall" Ms ASH I 18a, and again,

"The eye which is the window of the soul, is the chief means whereby the understanding may most fully and abundantly appreciate the infinite works of nature; and the ear is the second; inasmuch as it acquires its importance from the fact that it hears the things which the eye has seen. * * * If you call painting "Dumb Poetry" then the painter may say of the poet that his art is "Blind Painting." * * * Although the poet has as wide a choice of subjects as the painter, his creations fail to afford as much satisfaction to mankind as paintings, for while poetry attempts with words to represent forms, actions and scenes, the painter employs the exact images of the forms in order to reproduce

these forms. Consider, then which is more fundamental to man, the name of the man or his image? The name changes with change of country; the form is unchanged except in death' Ms ASH 1 Fol 19r, and (continuing in a most interesting discussion as to the relative merits of sculpture and painting too extended to reproduce here) he adds: 'As practising myself the art of Sculpture no less than that of painting and doing both the one and the other in the same degree, it seems to me that without suspicion of unfairness I may venture to give an opinion as to which of the two is the more intellectual and of the greater difficulty and perfection' Ms ASH I Fol 25r, and again: 'The comparison of poetry, painting, and sculpture resolves itself into a consideration of the relative importance of the senses to which these manifestations of art make their appeal."

Leonardo's greatest work of art and one of the world's greatest paintings, "The Lord's Supper," needs no description here. A critic has said of it: "It has a gallery of its own in the way of



Furnace for acids.

copies; a library of its own in the form of description; an epic of its own in the annals of maltreatment." His next most important work of art is the famous portrait of "Mona Lisa," and others more or less well known whose authenticity is unquestioned are the "Virgin of the Rocks," "Saint Anne," "The Holy Family," "The Adoration of the Magi," "S. Hieronimus," etc. A severe critic of Leonardo has said: "His fame as a painter rests upon

four or five unfinished or half ruined paintings;" and again: "His writings and the thoughts buried in them were not known to his contemporaries nor yet, with the exception of a few fragments, to those who came after him. It was reserved for the nineteenth century to see them published." Vasari, the contemporary biographer, says: "It will be seen how Leonardo, by virtue of his genius as an artist, began many things but never completed anything, as it seemed to him that his hand could not attain to the artistic perfection in his works at which he aimed, because in his mind he formed and created such marvellous difficulties that they could never be expressed by the aid of hands, no matter how excellent the capability of which they were possessed."

Of Leonardo's work as a sculptor there is little or nothing left to the world that is authentic, although we have a number of references to his works, notably the model for the great equestrian statue of Duke Franceso Sforza. Jovinus, a contemporary historian, in the few lines he devotes to Leonardo mentions him as a painter, but accords great praise to his sculpture which he says Leonardo preferred to painting. We must also omit consideration of his interest in music and pageantry to which his notes contain numerous references, not only in the text but in sketches of various types of musical instruments designed by him, and costumes, decorations, and devices for court festivities and tournaments in which he coöperated.

PHILOSOPHY.

Leonardo's philosophical writings extend over the whole realm of speculative and natural philosophy, although he had a contempt for metaphysics; and in matters of ethics as well as science he reached his conclusions by a process of observation and experimentation, and drawing deductions therefrom rather than by recognizing the dictum of revelation of an external superior authority.

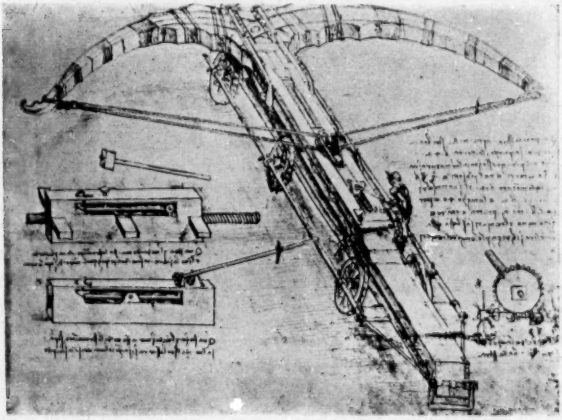
In matters of religion he seems to have been to a considerable extent an agnostic, but his doubts and weak faith and beliefs did not lead him into the kind of "pernicious activity" which led Galileo, Savonarola, Giordano Bruno and others into serious conflicts with the established church.

He seems to have escaped placing himself in the attitude of open hostility to the tenets of the church, and while he has given

expression by the sarcasm of pen and pencil to his opinion of priests and monks, it is known that he died reconciled to the church.

It is difficult, from the mass of available material, to give an adequate conception of his philosophy which in many respects was not always consistent and was subject to change, as appears from a number of contradictions contained in his notes in which his opinions became modified or changed.

A few quotations which reflect the contemplative side of our



Catapult for throwing heavy darts and arrows.

subject in language which is often lofty and poetic, although thoroughly modern in its fundamental concepts, may be of interest:

"O wonderful necessity! Thou with mighty reason obliges all effects to follow for their causes and with mighty and irrevocable laws forces every natural action with a brief operation to obey you. O Mighty Action! What ingenuity could penetrate such nature—what tongue could explain such marvels. This directs human discourse toward divine contemplation." Ms CA 345vb

"And Thou, O Man, who by these my labors doest look upon the marvelous works of nature, if thou judgest it to be an atrocious act to destroy the same, reflect that it is an infinitely atrocious act to take away the life of man. For thou shouldst be mindful that though what is thus compounded seem to thee of marvelous subtlety, it is as nothing compared with soul that dwells within this structure, and in truth, whatever this may be, it is a divine thing which suffers it thus to dwell within its handiwork at its good pleasure, and wills not that thy

rage or malice should destroy such a life, since in truth he who values it not does not deserve it." Ms WA Fol A2r

"There will be many who will abandon work and labor and poverty of life and possessions and will go to dwell among riches and in splendid buildings, pretending that this is a means of becoming acceptable unto God." McCurdy, L.d.V. Note Books, p. 276.

"Aristotle says in the third chapter of his ethics: Man is worthy of promise or of blame only in these things which are in his power to do or not to do." Ms CA 284b; 865b

"Nature is so delightful, so abundant in her variety that among trees of the same variety one does not find one tree which resembles another and not only the trunk, but the branches, the leaves and the fruit—not one of these can be found the same as another." Solmi, Frammenti Letterari e Filosofici, p. 12.

"Every act of nature is accomplished by her in the quickest possible time and most direct manner." Ms G Fol 75r

"Our life is made by the death of others." Ms H, 41b

"Every action is exerted through motion." Ms CA Fol 83v

"Motion is the cause of all life." Ms Tr Fol 36r

"Before deducing a general rule from the specific case, try the experiment two or three times and observe if the experiments always give the same results." Ms A Fol 47r

"Science is that product of the mind which has its origin in fundamental principles beyond which you cannot go; as in the science of Geometry, which, beginning with the surfaces of bodies, has its origin in lines the delimitations of these surfaces. But with this we are not content, because we know that the line has its origin in the point, and again beyond this we cannot go, etc."

Solmi—Frammenti Letterari e Filosofici, page 77.

(And this word of warning to future generations of engineers:)

"Effect of my rules: If you ever asked me what these rules accomplish or of what good they are, I should answer that they keep a restraining hand on Engineers and Investigators—teaching them not to promise themselves or to others impossible things and in consequence may be considered either crazy or imposters."

ASTRONOMY.

Leonardo's researches on astronomy and geology have, throughout, the stamp of independent thought and mature reflection based on his observations and investigations.

He quotes the ancients only insofar as is necessary to refute their arguments which he often presents and confutes in the old form of question and answer.

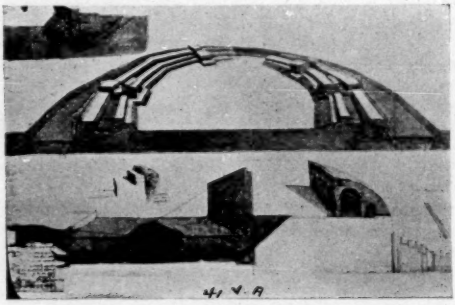
The spherical form of the earth he takes for granted as an axiom, and he anticipates Newton, to a certain extent, by pointing out the universality of gravitation not merely on the earth, but in the moon also. It appears he made use of magnifying glasses to a limited degree, arranged, perhaps, like a crude telescope, for he was

in a position to study the spots on the moon more closely than could be done with the naked eye, as appears from this sentence in his notes Mc C A Fol 190r: "Construct glasses to see the moon magnified." Among his conclusions on cosmic problems are the following:

"The earth is a star." Ms F Fol 56r—Ms C A 111b: 345b

"The sun does not move." Ms W L Fol 132r

"I say that the moon has no light in itself and yet is luminous, it is inevitable that its light is caused by some other body? and again so much of it (the moon) as faces the sun is illuminated and



Works of defence—moats, parados, redouts, galleries, etc.

of that illumined portion we see so much as faces the earth, etc., etc." Ms Bm Fol 94v

"Beyond the sun and us there is darkness and so the air appears blue." Ms W XXVI

"Every man is always in the middle of the surface of the earth and under the zenith of his own hemisphere and over the centre of the earth." Ms Tr 28

"Take the measure of the sun at the solstice in mid-June" Ms Bm Fol 78v; referring to the observance of an eclipse without pain to the eye, he says: "Take a piece of paper and pierce holes in it with a needle and look at the sun through these holes." Ms Tr Fol 6v(12)

He refers to the equator, the line of the horizon, the ecliptic and the meridian, saying of them: "These lines are those which

in all their parts are equidistant from the centre of the globe." Ms Bm 176a

Referring to the stars, he says: "The stars are visible by night and not by day because we are beneath the dense atmosphere, which is full of innumerable particles of moisture, each of which by itself when struck by the rays of the sun reflects a radiance, and so these innumerable bright particles conceal the stars, and if it were not for this atmosphere the sky would always display the stars against its darkness." Ms F Fol 5v

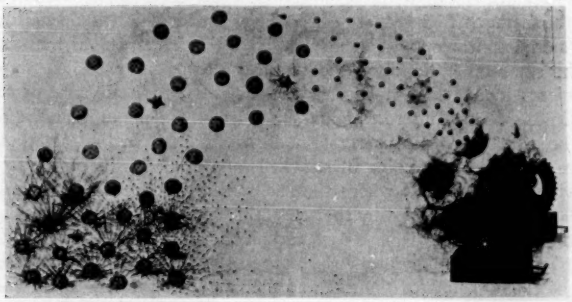
GEOLOGY.

In the field of geology and physical geography, Leonardo found much that aroused his interest, much that was mysterious and inexplicable, but he endeavored to formulate reasons for what he saw and he made abundant observations in his notes, statements from which it appears that he was far in advance of his time. We find interesting and extended comments in his notes on the probability of a universal flood having covered the earth, and reference to the finding of sea shells and other fossils on the tops of high mountains where the shells, being heavy objects, could not have been carried by the sea. Ms Leic Fol 9v. In discussing this problem he displays a remarkable knowledge of the physical geography of many parts of Europe as he does when he discusses the ebb and flow of the tide and the height of the rise of the tide in various places. There is also a very interesting and extended presentation of the subject of why the water in the sea is salty; discussions on the relative areas of sea and dry land and the relation of the sea to vast subterranean water courses, in which he was a firm believer. The origin and flow of rivers, the elevation of the earth into mountains and their erosion into valleys, and the origin of wind and waves all occupy his attention, and he gives a wealth of observational details to substantiate his opinions as to the causes of the various phenomena. "The water wears away the mountains and fills up the valleys, and if it had the power, it would reduce the earth to a perfect sphere."—McCurdy, LdV Note Books, Page 101 from Mss C A 185 v c. How he obtained such an enormous amount of observational material covering the physical geography of practically the whole of the then known world, is one of the many mysteries surrounding the manuscripts which have not received an adequate explanation.

The notes contain records of many exploring excursions to the lakes and mountains of northern Italy, and there is a record of a genuine alpine ascent of Monte Rosa—with its peaks reaching a height of over 4600 metres (15,000 feet)—and he gives a careful description of the height of the clouds, the extent of the snow in the summer season, effects of hail, etc.

BOTANY.

As a painter, studying with care the landscape and the effects or light and shade on the verdure of trees and plants, he was quite naturally led to study the various forms of trees, the division of



Mortars and exploding shrapnel.

the branches and the form and arrangement of the leaves. While he refers to these in his "Treatise on Painting," he calls attention to the fact that he would treat the science of the trees and plants, *i.e.*, their botanical relations, elsewhere in his manuscript. We find pictured in his notes, particularly in the series in the Windsor collection, a number of flowers and leaves, with the outline of their form, petals and stamens reproduced with scientific precision, rendering any description quite unnecessary. Leonardo found that the leaves of plants grow on the twigs in an invariable order. "The branches of the plants grow on the limbs just as the leaves grow on the twigs of the same year; the leaves have four methods of growing above each other: The first and more general arrangement is that the sixth always grows above the sixth which is underneath it; the second arrangement is that the two that are the

third ones on top are above the two that are the third ones underneath; and the third arrangement is that the third one on top is above the third one that is underneath." Ms G 33a. Leonardo has thus observed the law that an unvarying number of leaves separate each leaf from those which vertically precede and follow it. He omits to give the fourth method of growth, but in another note, regarding the elder tree, he points out the case of opposite leaves which grow two and two (the lilac). In text-books on botany the credit for discovering these regular arrangements of leaves is usually assigned to others under a much later date.

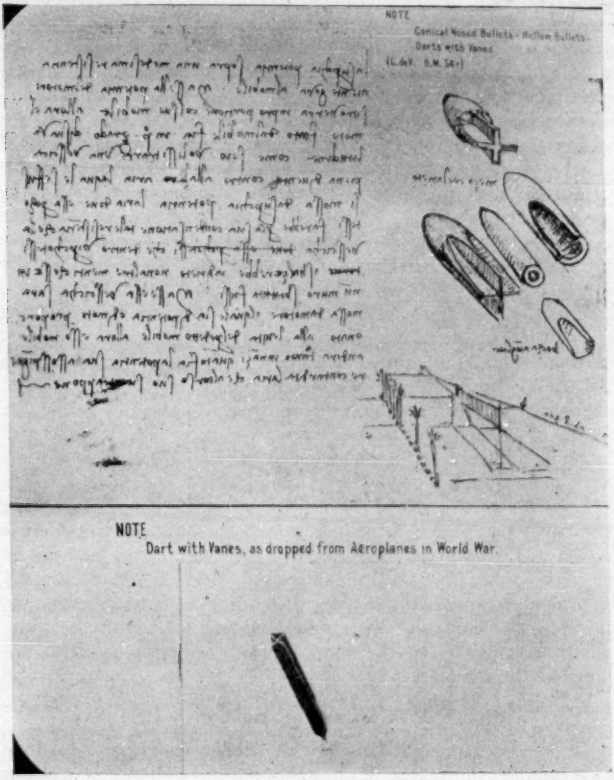
He gives as the reason for the regular arrangement of the leaves on the branches: "Nature has so placed the leaves of the latest shoots of many plants that the sixth leaf is always above the first, and so on in succession, if the law is not accidentally interfered with. This is of a two-fold advantage to the plants; first, as the branch or the fruit, the year following, grows at the axil of the leaf the rain which falls on the branches can drop and nourish the bud, these drops being held in the cavity formed by the axil of the leaf; and the second advantage to the plant is that when its branches grow the following year, the one does not cover the other, because the five branches grow turned in five different directions and the sixth grows above the first at some distance." Ms G Fol 16v. Passing over some interesting observations as to the arrangement of the limbs on the main trunk of trees and the relation of the combined cross section of the branches to the cross section of the limbs as determined by the flow of sap, we come to the most important of all, that Leonardo first discovered that by the annual ring growth of trees their ages could be determined; the relative thickness of the rings indicating wet or dry seasons, and the eccentricity of the rings indicating their relation to the points of the compass.

ANATOMY AND PHYSIOLOGY.

In no department of human knowledge has Leonardo done more important research work, exhibited more distinctly modern tendencies, and combined in such remarkable manner his abilities as an artist-illustrator and scientific investigator, than in the realm of physiology and anatomy, particularly the latter.

As a painter he speaks everywhere of the absolute necessity of a complete knowledge of the anatomy of the human body, its struc-

ture, proportions, and muscular development, but in his scientific researches and dissections of human cadavers he went far beyond



Conical bullets and darts with vanes—dart with vanes dropped from aeroplanes in the World War.

the requirements of a sculptor or painter and interested himself in observing the structure, relations and functions of every organ of the body. Unfortunately, his notes and sketches on anatomical

subjects, as in fact on every subject they touch upon, are distributed in a fragmentary form throughout his manuscripts, although most of them appear on the sheets brought together in the Windsor collection and recently splendidly reproduced in six large folio volumes by three learned specialists under the auspices of the University of Christiana. The reproduction consists of magnificently executed facsimile sheets, a transcription into the original Italian, and parallel translations into English and German.

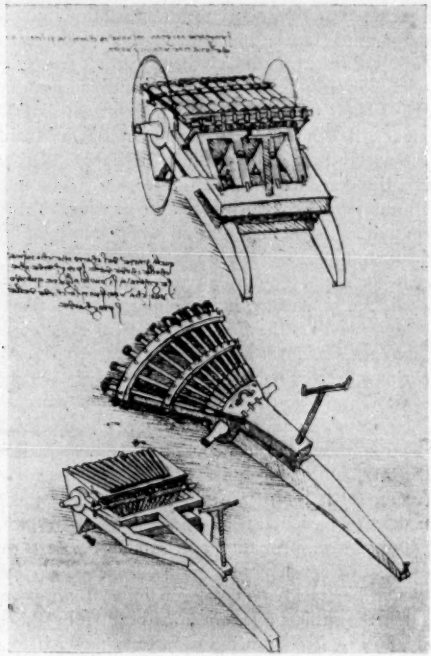
It will be difficult to assign to Leonardo his proper place as a pioneer worker in this special field, but with this recent publication he has come to be generally recognized by the medical profession as the founder of Physiological Anatomy. Dr. William Hunter, an eminent authority, had previously said that "Leonardo was at that time the best anatomist in the world. His studies of the bones and muscles are exhaustive and he considers them not only in their individual structure, but in their interrelationship and combined functioning."

A recent commentator on his work, from the medical profession, has said: "Imbued with the importance of the static and mechanic laws to which the human frame is subjected he rises to the most modern standards of illustration which the painstaking work of the past decades has evolved. The way in which he draws the normal curvature of the spine, adjusts his skulls with intention in a definite horizontal plane, and fixes the pelvic inclination, would make one think that he adopted the standards decided upon in the latest anatomic and anthropological congresses. He illustrates the complex action of antagonistic muscle groups by means of tape models, the schematic drawings of which at once elucidate flexion and extension, pronation and supination. He also knows the advantages of clear demonstration to be derived by serial cross sections, which he employs on a lower limb. By appropriate sections through the skull, he shows most beautifully the pneumatic sinuses and their interrelation, a demonstration which no anatomist up to modern times had attempted."

In method Leonardo was the forerunner of both Vesalius and of William Harvey, and although Leonardo knew the difference between the arteries and veins and that the blood circulated throughout the body, he did not, however, discover the law and processes involved in the circulation of the blood which was discovered later by Harvey.

He was familiar with the authorities and quotes from Mondino's Anatomia, and must have known of Galen's work, as he did of that of the learned Arab doctors.

At a time when the church taught the sacredness of the human body and was ready to excommunicate those who practiced dis-



Metrailleuse.

section, he pursued his studies relentlessly, and it was owing to an information laid against him concerning these experiments that the Papal favor was withdrawn from him and he was obliged to leave Rome in 1515. Let us reproduce a few of his anatomical notes: Speaking of the desirability of watching an anatomical demonstration rather than studying a drawing, he says:

"If only it were possible to observe all the details shown in these drawings in a single figure; in which, with all your ability, you will not see nor acquire a knowledge of more than some few veins, while in order to obtain an exact and complete knowledge of these I have dissected more than ten human bodies, destroying all the various members and removing even the very smallest particles of the flesh which surrounded these veins, without causing any effusion of blood other than the imperceptible bleeding of the capillary veins." Ms WAN IV Fol 167r

"With a saw (dissection) cut through a head at the eyebrows to find the reason of the simultaneous movement of the two eyes, etc."

"Write in thy anatomy what proportion there is between the diameters of the lenses of the eye, and the distance from these to the crystalline lens." Ms CA Fol 345v

"Who would believe that so small a space could contain the images of all the universe? O mighty process! What talent can avail to penetrate a nature such as thine? What tongue will it be that can unfold so great a wonder? Verily none! This it is that guides the human discourse to the considering of divine things. . . . Here the figures, here the colors, here all the images of every part of the universe are contracted to a point. O what a point is so marvelous!" McCurdy, L.d.V. Note Books, page 117, from Ms CA. 345vb

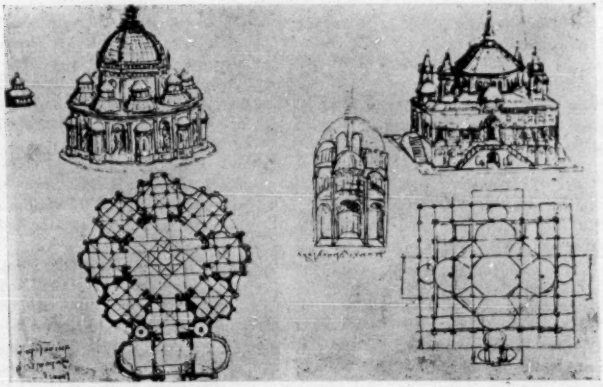
"Walking of man is always like the universal manner of walking of quadrupeds. As they move their legs diagonally like a horse in trotting, so man in walking moves his four members diagonally; that is, if he puts forward his right foot in walking, he brings forward at the same time his left arm and vice versa." Ms CA Fol 297r

"The death of old men, without fever, is caused by the veins, which, going from the spleen to the liver, have their skin become so thick that they close and no longer give passage of the blood which nourishes them. The continued flow of blood in his veins caused the veins to become thick and callous so that at last they close and prevent the blood from flowing." "An old man, a few hours before his death, told me that he had lived a hundred years and that he did not feel any bodily ailment other than weakness, and thus while sitting upon a bed in the Hospital of Santa Maria Nuova at Florence, without any movement or sign of anything amiss he passed away from this life. And I made an autopsy in order to ascertain the cause of so peaceful a death, and found that it proceeded from weakness through failure of blood and of the artery that feeds the heart and the other lower members which I found to be very parched and shrunk and withered; and the result of this autopsy I wrote down very carefully and with great ease, for the body was devoid of either fat or moisture, and these form the chief hindrance to the knowledge of its parts. The other autopsy was on a child of two years, and here I found everything the contrary to what it was in the case of the old man." Ms WAN B Fol 10v

Leonardo's special attention was drawn to the heart and lungs and he made numerous cross sections of the heart, particularly the bovine heart, and he distinguishes the two ventricles and the two auricles and characterized the heart as a muscle, the first in strength and potentially among all the other muscles. It is difficult to under-

stand why, with the knowledge of Dynamics and Hydraulics he possessed, he did not discover the whole mechanism of the circulation of the blood, and this mystery is deepened by the sentence appearing in his notes: "Do not the veins of the lungs send back to the heart the blood, when they contract to expel the air?" Klebs, Leonardo da Vinci, page 12.

The nervous system also passed under his scalpel and his whole dissective technic is a marvel even to the modern surgeon. Note, for instance, the representation of the brain ventricles by a cast



Architectural designs for church.

obtained through injection of wax into the third ventricle and his suggestion of "putting eye balls into white of egg, to coagulate them, and then make sections for the study of the eye." Klebs, LdV, his Anatomical Studies, page 14.

It is said that he dissected more than thirty bodies of men and women at various ages, besides many animals. No one before him represented in drawing the muscles, organs, and nerves as he did, and his anatomical work throughout is characterized by astonishing accuracy, deep physiological insight, and zealous endeavor to get at the facts.

We must dismiss at once the thought that his anatomical work was undertaken and recorded merely for artists and not for medical students and for the professional anatomist.

CHEMISTRY.

An inspection of the facsimile drawings show many sketches of chemical retorts, stills and furnaces which he used in experimenting with the various recipes he gives for perfumes, oils, the preparation of colors and varnishes, acids for etching metals, mixtures for fireworks and poisonous gases. He illustrates a carefully designed reverberatory furnace and a still with condenser provided with a constantly flowing stream of cold water. But of all his chemical observations the most interesting are those relating to the burning flame, and here he is several centuries ahead of his time in outlining the theory of the processes of combustion in the candle flame.

His notes say: "Where flame cannot live, there breathing animals cannot. The light (candle) flame creates a vacuum and air rushes to relieve the vacuum. Elementary fire continually consumes the air by which it is partly nourished and would find itself in contact with a vacuum if the surrounding air did not rush in to refill it. Smoke is generated in the middle of the flame from the candle." Ms C A Fol 237v. "Flame arranges first the matter by which it is nourished and then nourishes itself thereon. Excessive wind destroys flame, a moderate wind nourishes it." Ms C A Fol 270r

His ceaseless dabbling with oils and preparations to be applied to fresco paintings is no doubt responsible for the loss to the world, as asserted by some of his contemporaries, of two of his great masterpieces, "The Last Supper" and "The Battle of Anghiari," both ruined—the former partly, the later utterly—by defective application of the tempera or oil to the wet plaster, resulting in its peeling off very rapidly.

GEOMETRY.

As we examine the manuscripts we find portrayed an infinite number of figures made up of circles, cusps and interlaced figures of circular segments, literally many thousands of them, with every conceivable combination of a line and circular arc that could possibly be inscribed in a circle. What could have been the purpose of these curious diagrams, whether they were studies which had a scientific aim or were meant to serve an artistic or practical purpose, we do not know, but they have been made the basis of many interesting decorative designs of rosettes and architectural ornaments.

Model city plan—upper and lower level streets.

The manuscripts contain references which indicate Leonardo's interest in arithmetic, algebra, geometry and mechanics—and his notes abound in computations which indicate a facility in making

use of formulæ and in making calculations in mechanics and physics. He is said by competent authority to have invented the plus (+) and minus (−) signs and other notations, such as the use of letters of the alphabet for numbers and combinations thereof, etc., which are still in use. He sought a method to develop curved surfaces on a plane, to distinguish between lines of single and double curvature, and proceeded on the basis that surfaces were the limits of all bodies and lines the limits of surfaces. One of the geometric propositions he lays down is: "The largest sphere which can be inscribed in a given cube has a surface equal to the largest cylinder which can be inscribed in the same cube."

He coöperated with Luca Paccioli in preparing his work, Divina Proportione, which undertook to apply to the human body, to architecture and to the construction of the letters of the alphabet, certain basic geometric proportions, and Leonardo executed the drawings in which inscribed polyhedrons are marvellously shown in perspective.

In addition to these geometric designs we find a number of figures involving complicated rope-like labarinthine interlacings, such as we often see in more simple form in connection with illuminated initials, an example being a kind of trademark or seal marked "Leonardi Academia Vi-ci," presumably for the Academy which he is said to have founded at Milan, but of which we have very little knowledge.

PHYSICS.

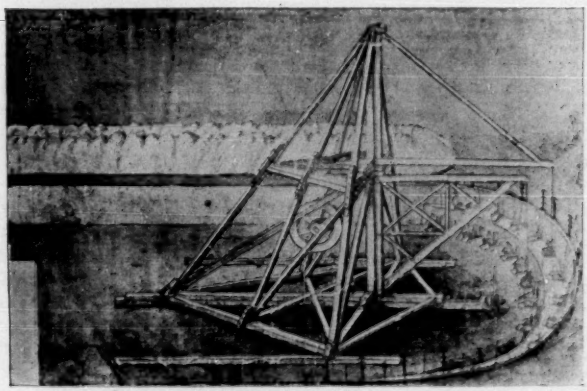
It is in the department of physics and particularly of mechanics of which he said: "Mechanics is the paradise of the mathematical sciences, because through it one reaches the fruition of the mathematical sciences," Ms E Fol 8b, that the great master has displayed to particular advantage his extraordinary reasoning faculties and his complete control of research and experiment in deducing the fundamental laws by a process of inductive reasoning, in the application of which he undoubtedly antedated Bacon.

In connection with his work as a painter he became much interested in the phenomena of light and shadow—umbra and penumbra—and his notes contain innumerable sketches of sources of light with bodies of different shapes which in interference cast shadows of different shapes and degrees of density.

A series of interesting studies on sound, its propagation in

air, in liquids and in solids, its reflection, production of echoes, etc., is presented to us in the notes. The discussion of force, impact, pressure and velocity in their relation to mechanics and dynamics, occupies many sheets, and his experiments and calculations are supplemented by numerous diagrams and sketches.

"Why the thunder lasts for a longer time than that which causes it; and why immediately on its creation the lightning becomes visible to the eye, while the thunder requires time to travel, after the manner of a wave, and makes the loudest noise when it meets



Excavating machine for canals.

with most resistance."—McCurdy, LdV Note Books, Page 92 from Ms. K 110 (30) v.

The numberless arrangements of pulleys and cords, in every imaginable combination, and calculations of weights and equilibrium of the systems lead up to the practical employment of these arrangements in lifting and hoisting machines of various kinds and in powerful rope mechanism for the tensioning of beams and springs for stone and dart-throwing engines of war.

His constant aim to establish laws or rules based on his experiments and investigations lead him to generalizations which, while they may not always be scientifically exact in the light of modern science, nevertheless bear evidence of acuteness of observa-

tion and are expressed in terse phraseology. We note, for instance, the following:

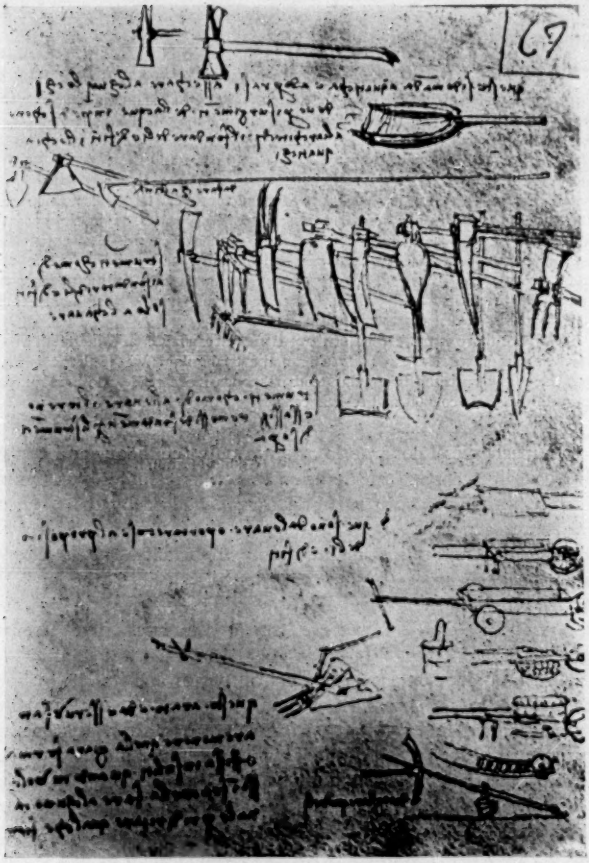
"If a given force moves a weight a certain distance in a certain time, the same force will move the half of the weight the same distance in the same time or the whole force will move all the weight in half the time half the distance, or the whole force in half the time will move all the weight half the distance." Ms F Fol 26v. "Force never has weight, but it always has the effect of weight." Ms CA Fol 382r. "Among wheels of the same diameter that one will be most easily revolved which is supported by the smallest shaft." "The friction of bodies is of as many different degrees as are the degrees of lubricity of the bodies which are rubbed together. In those bodies of which the surfaces are smooth, friction is least. In bodies of equal lubricity the heavier body offers the greater resistance in friction. Every body resists in friction with a power equal to one-fourth of its weight, the planes being level and the surfaces smooth." L.d.V and his works, Heaton and Black, p. 151.

"Where there is more contact there is more resistance, and the teeth of the square screw have a larger surface than the triangular (V) teeth; it is there that the screw with the triangular teeth responds more readily to a movement, because it has less contact and resistance."

In mechanics Leonardo knows not only the theory and resolution of forces applied to the lever and oblique forces, but the resistance to the propulsion of ships as influenced by the form of the submerged body, the influence of the centre of gravity on bodies at rest and in motion, and most important of all, he clearly establishes the broad principle of virtual velocities, the basis of the modern science of analytical mechanics.—Wilhelm Elsässer, Bedeutung L. d. V. für die Exacten Wissenschaften. Preuss. Jahrbücher, 1899.

We find also some experiments on steam and its application, making use of its pressure, for instance, in a steam gun, the "architonitro," and also to move a weight or piston. It remains to speak of perpetual motion for which we find a number of designs of apparatus of types that have come to be well known, but Leonardo frequently emphasizes the absurdity of achieving perpetual motion and cries out: "O Speculators about perpetual motion, how many vain chimeras have you created in that quest? Go and take your place with the alchemists."

We have referred to Leonardo's services as a Military Engineer and that he was an expert in every then known branch of military science appears from page after page of his manuscripts.



Construction tools: Picks, shovels and evolution of the wheelbarrow.

MILITARY SCIENCE.

We have, first of all, portrayed a remarkable series of engines of war of the general types used by the ancients—catapults, balaestre,

mangonels and cross-bows. The majority of these weapons are based on the bending of heavy wood or metal springs or the torsional power of twisted rope, the tension being applied by screw gearing, levers or pulley blocks, operated in the very large machines by animal power.

Cannon were coming into use and he shows in great detail the methods of making the cores and moulds for casting cannon, designs for the breech-blocks of breech-loading cannon, and in one case pictures a complete cannon foundry with cranes in operation and workmen in action in poses full of energy as he alone could sketch them. We find not only cannon of heavy and light calibre, but revolving cannon of the type of the metrailleuse and multi-barrelled guns mounted on gun carriages, some of them of truly modern design.

We find pictured and described various types of two and four wheeled vehicles, for one and two horses for the transportation of subsistence and the various other services rendered by the military train.

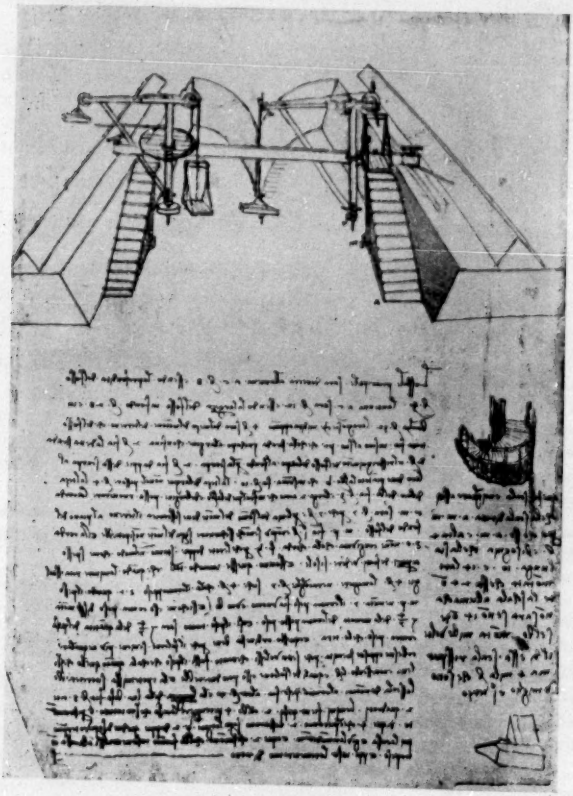
But we must express our admiration for the built-up gun with accurately fitted, tapered steel bars, wire-wound into a compact barrel, and the very highest mechanical skill is shown in a very complete and altogether modern appearing machine operated by water power for automatically drawing these tapered trapezoidal bars.

These machines are shown in detail with their principal working parts appearing on an enlarged scale, so that they constitute complete working drawings in accurate perspective.

An extended series of sketches of ancient and medieval hand weapons covers several sheets and they appear in complete and orderly arrangement, each spear, battle axe, pike or slung shot carefully sketched and its method of use indicated. We find here and there sketches of flying military bridges for crossing moats and canals; and also drawbridges, pontoons and folding bridges that fold into the side of the canal so as not to impede navigation.

There appear numerous outlines of fortresses, fortified castles, and defensive works, some of them of the polygonal type carried out in completeness of detail that suggests a Vauban. We have a suggestion of the competition between the offensive power of cannon and the defensive resistance of brick, concrete, and earth works in the statement, "Because the artillery of to-day

have increased in power by three-quarters, one must also increase the resistance of the walls by three-quarters," Grothe, LdV als



Canal excavating machine.

Ingenieur and Philosoph, p. 65, and again in speaking of brush-work shields for fortification of walls, he says:

"That blow will be of greater force which is given against a resisting barrier and so is returned; that will be the weaker which meets a barrier of less resistance. Thus it follows that rigid walls do not withstand heavy blows, but hay and sod in which the fury of balls driven from powerful cannon is absorbed, do withstand the blows." Ms CA Fol 41va

We have illustrated grape-shot, chain-shot, shrapnel, including conical and pointed shot and bullets, and the advantages of the latter are discussed with a reference to the helical rifling of cannon. There would appear to be a reference to cartridges in these words:

"The mounted carabineers must be provided with slender and simple tubes full of powder, with the ball inside so that they can be readily inserted and in this way an immense number of the enemy will be vanquished, and these carabineers must form in squadrons the same as arbalesters so that one part of them can fire while the other loads; but first be sure to accustom the horses to these noises or better stop up their ears."

One of the sheets shows a collection of ladders of all kinds, evidently intended for military use in scaling walls, and on another page we have exhibited a scheme for repulsing the besiegers by overthrowing them from the wall by thrusting out a hidden wooden framework. We have illustrations of attacking ships by the use of Greek fire by fire-boats and by sinking ships with a boat equipped with a submarine projecting ram in reference to which he says:

"Why is it that I do not describe my method of remaining under water? How long can I stay without eating?—these I do not publish or reveal on account of the evil nature of men, who would practice assassination on the bottom of the seas, by breaking the hulls of boats and wrecking them with all on board; while I tell about other means of submergence there is no danger from these because on the surface of the water there appears the mouth of the aspiration tube floating on skins or cork." Ms Leic Fol 27b

He is quite familiar with mining and countermining and gives curious instructions for detecting the noise made by the sappers in their operations.

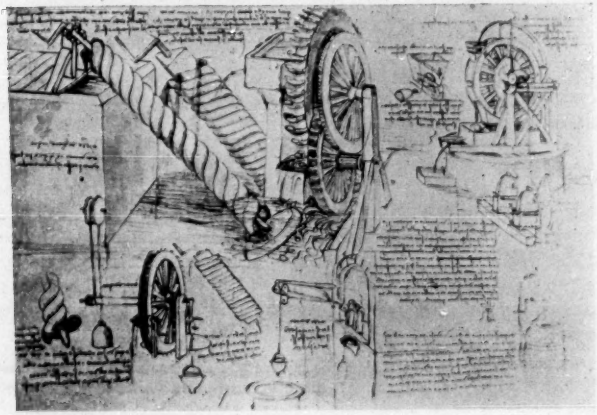
But we must be particularly interested in the anticipations of a number of instruments of warfare that were conspicuous in the World War, such as the defensive steel headgear, the defensive breastplate and movable shield, the tank—yes, and poisonous gases and gas masks, as well, for we find the following note:

"Throw among the enemy ships, with small catapults, chalk, pulverized arsenic and verdigris. All who inhale this powder will be asphyxiated by

breathing it, but be careful that the wind be such as not to blow back the fumes, or else cover your nose and mouth with a moist cloth so that the powder fumes cannot penetrate." Ms B Fol 69v

CIVIL ENGINEERING.

Some of the excellent drawings, many of them colored, appearing in the manuscripts are maps and topographical plans of various kinds, probably sketches for use in connection with his plans for canals and irrigation works. Of the utmost interest is a map



Water lifts—Archimedian screw.

indubitably by the hand of Leonardo to which has been assigned the date 1513–1514, found among the manuscripts of Windsor. In a report entitled "Memoir on a Mappemonde by Leonardo da Vinci," by N. H. Major, Esq., F. S. A., he states as to his map:

"First: That it is the earliest map yet made known to the world on which the name of America stands inscribed.

"Second: That it is the earliest known map on which the severance of the western coasts of America from their previously supposed continuity with Asia is recognized.

"Third: That it is the only map, as yet known, which contains an indication of the early fancied existence of a great Southern continent anterior to the discovery of Magellan's Straits, etc."

(*To be concluded*)

DISPOSAL OF INDUSTRIAL WASTES AND STREAM POLLUTION.*

BY

C. A. EMERSON, JR.

Chief Engineer Pennsylvania Department of Health.

PROPER methods for disposal of industrial wastes, which consist of liquids contaminated by the process of manufacture, are essential for prevention of stream pollution or stream despoliation.

Official action to control the discharge of these wastes has not been taken in most instances until after nuisance conditions have arisen or damage has been done to lower riparian owners.

Several general reasons may be advanced for this disregard of public rights by owners of industries and apparent lethargy on the part of government officials; an unfortunate lack of appreciation of the damage to be caused by discharge of the various kinds of industrial waste; former ignorance as to economical and effective methods of treatment; reluctance to make expenditures for installation and maintenance of treatment works when such expenditure might seriously affect the profits of the industry and lastly—want of uniform and definite control legislation.

The result of this delay is particularly noticeable in an industrial State such as Pennsylvania. Even now many of our large streams are so grossly polluted by industrial wastes that their return to a condition of reasonable cleanliness is a task of great proportions, but one which is by no means insurmountable.

The cost of treatment of industrial wastes to prevent stream pollution should undoubtedly be borne by the industries responsible for the discharge. Unfortunately the majority of these wastes are refractory and many of the treatment processes are expensive and relatively inefficient. The enactment of rigid control legislation is only a portion of the remedy and might easily place such a burden upon the industries as to seriously disturb the prosperity of the State. Economical and effective methods of treatment must be developed and proven by actual plant operation before we are ready for stringent legislation.

* Presented at a meeting of the Mechanical and Engineering Section held Thursday, March 3, 1921.

The owners of the industries, as a rule, recognize their moral responsibility and are ready to install treatment processes when it can be shown that there is reasonable assurance of success at a not prohibitive cost.

Methods of treatment which have been developed in the past have oftentimes been unsatisfactory either because of the expense of the treatment process or else because of misconception of the character and degree of treatment required.

There was formerly a tendency to believe that most industrial wastes could be given treatment of the same general character and that all processes should be carried to such a degree of refinement that the effluent discharged into the stream would be clear, colorless, tasteless and free from chemical and bacterial poisons. The judgment of to-day is upon a more rational basis and takes into consideration the great variation in the physical and chemical composition of the different wastes requiring special treatment processes; the relative values of the industries to the State; the present uses and probable future development of the water course and the ability of the stream to absorb and purify the waste by natural agencies.

Another forward step has been the realization that many of our industrial wastes contain matters of value and that improved methods of manufacture which make fuller and better use of the raw materials not only lessen the cost of the commercial product of the industry but reduce or even entirely remove a portion of the objectionable characteristics of the industrial waste, thus simplifying the methods and lowering the cost of treatment.

To secure the desired results requires joint investigations by engineers and chemists, backed by the coöperation of the manufacturers, and preferably under the guidance of the State, for the benefits derived react on the prosperity of the entire Commonwealth.

These principles can well be illustrated by considering methods of treatment now in use or in process of development for some of the more common industrial wastes.

You are doubtless familiar with the objectionable appearing and nuisance producing wastes from tanneries. These wastes have been studied for years, and the development from the first crude settling basins, installed and then promptly neglected, is interesting. Tannery waste carries much matter in suspension; may be alternately acid and alkaline in reaction; is objectionable in color and

because of its avidity for oxygen and its active chemical constituents will cause a nuisance when discharged into a small stream. In line with the principle of conservation, it has been found that the spent tan liquors discharged from the vats can be concentrated by evaporation and again used in the tanning process. Much of the hair from the hides, which was formerly wasted, is now being reclaimed by flotation combined with fine screening, and has a ready market. The waste from the lime vats is settled in properly designed and carefully operated sedimentation basins, and the sludge is either dried or is dried and also recalcined and used as a fertilizer. The bits of flesh scraped from the inside surface of the hides are used by glue manufacturers. After the removal of these various objectionable constituents, the liquid waste remaining can oftentimes be discharged into a city sewer system or into a large stream without causing nuisance, or if the receiving body of water is so small or its uses are such that further treatment is required, the liquids can be subjected to precipitation by chemicals or the organic matter oxidized through violent agitation by compressed air and subsequently removed by sedimentation. The resulting effluent is free from objectionable color and is sufficiently stable to prevent the creation of a nuisance when discharged into a small stream.

Disposal of the liquid wastes from wool scouring plants, without creation of a nuisance in streams, has been furthered by development of processes for recovery of the grease removed from the wool in the cleaning process. Formerly the grease was recovered by treating the wastes with either naphtha or sulphuric acid, but recently centrifugal separators have been installed, similar in principle to those used in dairies for separating cream from milk, and are operating with marked success. The results obtained at one of the wool scouring establishments in the vicinity of Philadelphia may be taken as an illustration. The total liquid wastes of the plant amount to approximately 10,000 gallons daily. Of this volume, about 7000 gallons are contaminated with grease from the wool and are passed through the separators, yielding from 180 to 200 pounds of wool grease or crude lanoline a day, which is sold to the refiners at a price representing a desirable profit over the cost of operating the separators. Of equal importance to the sanitarian, the liquid wastes after removal of the grease, are susceptible of treatment by sedimentation and sand filtration at a moderate cost.

The wastes from the tar separators, the ammonia, benzol and naphthalene stills of by-product coke ovens and the wastes from gas works employing the water gas method of production, while not ordinarily polluting streams to a sufficient degree to cause objectionable conditions to those residing along the banks, are of particular importance because of the disagreeable tastes which these wastes impart to the water when used for domestic purposes. The types of water filtration plants in general use by municipalities will not remove the disagreeable tastes from a raw water contaminated by these wastes or by the products caused by the chemical combination of the active principles of the wastes. In fact, chlorine treatment of the water supply, which is in almost universal use as an adjunct to water filtration, apparently serves to accentuate rather than to diminish the objectionable taste. After application of chlorine, in the minute quantities ordinarily used in treatment of public water supplies, the tastes have been noticeable in dilutions as great as one part of the wastes to ten million parts of water. Treatment of these wastes, to be effective, must, therefore, be most complete. Fortunately, such method of disposal is now available and consists, simply, in excluding all such wastes from streams used as sources of public water supply.

At the coke ovens, all of the objectionable and taste producing liquid wastes are collected and used for quenching or cooling the glowing coke drawn from the ovens, thus passing into the air in clouds of steam. As an excess of the water is sprayed over the coke at a high rate, a portion is not evaporated at once, but passes through the coke into sumps beneath the quenching platforms and is recirculated by pumps to be evaporated during quenching subsequent charges of coke. Incidentally, the finely divided coke, formerly carried into the streams and lost with the excess quenching water, is now deposited in these sumps and salvaged, representing a saving which offsets the additional cost of operation of the circulating pumps. At the largest by-product coke oven installation in Pennsylvania the volume of contaminated water thus turned into steam is in excess of one million gallons daily.

At the gas manufacturing plants equally effective methods of disposal are in vogue. Waste waters from the gas washing chambers are freed from their burden of suspended tars and oils by passage through sedimentation and skimming tanks and the effluent water is recirculated through the process to again extract

oil and tar from the gas. The oil and tarry deposits in these tanks form the base for the road oils so widely used on our highways and represent a considerable income to the owners of the works. At one of our large Pennsylvania plants where operation methods did not permit of constant recirculation of the water and would at times have permitted excess waste water to pass to the river, thus reducing the effectiveness of the entire treatment process, the difficulty was remedied by using this excess water in the plant boilers, after it had been modified by sedimentation and coagulation, followed by filtration through coke strainers and sand filters. As this gas company purchases boiler water from the city system, and as the labor cost at the sand filter is nominal, the saving in the water bills is gratifying to officials of the plant.

Other wastes productive of much trouble are those from oil refineries and from oil wells. The installation of settling basins provided with skimming weirs have been of value in separating oil from the wastes from refineries and form a source of considerable profit to the owners. In certain oil producing districts large volumes of salt water are pumped to the surface with the oil, and this is particularly true when the oil wells are nearing exhaustion. The salt water discharged into the streams, after removal of the oil, causes salinity sometimes almost equaling that of the ocean. The remedy to date in Pennsylvania has been simple and effective, consisting merely of the discharge of the salt water back into the well outside the pump casing, thus preventing stream pollution and using the salt water as a medium for bringing more oil to the surface.

A form of stream pollution which formerly caused much complaint in certain portions of the great iron industry districts was due to the discharge of the so-called "acid-iron" or "pickling" liquors—that is, the waste from the process of acid cleaning of rust and scale from metal, prior to tin plating, galvanizing or other surface treatment of plates or tubes. When the strength of the acid had been reduced to such a degree that it was no longer effective for rapid removal of rust and scale it was the practice to discharge it into the streams, which caused destruction of fish life and also rendered the water unfit for drinking by livestock in the pastures or for boiler or other manufacturing purposes. These wastes consist principally of ferrous sulphate, with some free sulphuric acid and ferric sulphate. They are now evaporated in

acid-proof tubs, in the presence of iron turnings to neutralize the free acid and to reduce the ferric to ferrous sulphate, producing the crystalline ferrous sulphate of commerce. This procedure entirely prevents the discharge of waste acid from the pickling process, thereby abating the stream pollution.

Another interesting feature of waste disposal occurs in one of the branches of this general industry, the tin plate mills, where large quantities of palm oil and ordinary grain middlings are used in cleaning and polishing the tin plate. The palm oil has nutritive value, and as much of it is absorbed and retained by the middlings during the cleaning process, they are not discarded but are returned to the grain dealers and sold as cattle food. The mill owners simply pay what amounts to a rental charge for use of the middlings.

The most serious and extensive source of stream pollution in Pennsylvania is that due to the discharge of coal mine drainage, both from the anthracite and from the bituminous fields. The total volume of this waste is enormous. It has been estimated that over 850,000,000 gallons of water are pumped from mines in the anthracite fields each day, and that the volume pumped or flowing from mines in the bituminous regions of the State approximates 600,000,000 gallons daily. The total volume of this mine waste is about four times the volume of water furnished each day by the Philadelphia city waterworks.

The total quantity of free acid and acid salts carried by these mine wastes and by the discharge from the washeries has been estimated at over 3000 tons each day. It is impossible to even roughly estimate the total damage caused each year by this mine drainage, but recounting some of the havoc caused will serve to emphasize the seriousness of this pollution. The deposit on the stream beds of the fine coal carried by the mine drainage obstructs the normal flow channels, causing blockage of sewer outlets and increasing flood damage during high water periods. The sediment and the acid reaction destroy fish life. The increased hardness of the stream water is materially adding to the difficulty and expense of maintenance of at least ninety-six public waterworks in the State, supplying water to over 3,775,000 people, or nearly 45 per cent. of our total population. The increased cost to navigation, to industry, to municipalities and to individuals in the Pittsburgh district alone, has been placed at over $8,000,000 annually. The difficulties incident to control of this drainage are apparent

when we consider that, exclusive of many small wagon mines, there are in the neighborhood of twenty-six hundred active mines in Pennsylvania, and, furthermore, that discharge of mine drainage is not restricted to active mines, but also occurs by water continuing to flow from abandoned mines and by rain water falling upon the great culm and waste piles carrying acid drainage and fine material into the streams.

Mine drainage is not by any means uniform in chemical composition nor in physical appearance. The acid content varies widely in different districts and even from mines in relatively close proximity. Another striking difference is that the water of mine drainage polluted streams in the bituminous regions is relatively clear in appearance and ranges from a light yellow to a reddish brown in color, whereas the streams of the anthracite region carrying drainage from the mines, the breakers and the coal washeries are black and opaque in appearance, due to the great quantities of finely divided coal which they carry.

No exact figures are available for the tonnage of this coal which has been discharged into the streams flowing from the anthracite regions. It is possible, however, to derive approximate figures which are startling. The excess in coal taken from the ground over that marketed during the last sixty years has been estimated to be more than 500,000,000 tons. This excess was either allowed to escape into the streams or was placed in great storage or culm banks near the mines. As the contents of these culm banks is believed to have been approximately 125,000,000 tons, we are forced to consider that the difference between these figures, or 375,000,000 tons, represents the quantity of coal which has escaped into the streams from the mine fields.

Fortunately this enormous wastage does not represent a complete economic loss, for much of this coal has been deposited on the beds and along the banks of the streams and reclaiming operations have been practised for years along the Susquehanna, the Schuylkill, the Lehigh and their tributaries. The prevailing method for reclaiming the coal along the main streams is by small suction dredges, which pump a mixture of sand, coal and water from the bed of the stream. The discharge of the pump is over a screen, having six or eight meshes to the inch, and which serves to restrain the marketable coal while the finest particles of coal and much of the sand pass through the screen and are wasted. The

cost of reclaiming and marketing this "river coal," as it is called, is moderate, and it is much in demand, not only for use in large industrial boiler plants but in private homes. The shortage in freshly mined coal during the past three years has served to greatly increase the recovery of river coal and figures recently made public by the State Topographic and Geological Survey indicate that a total of about 2,000,000 tons were reclaimed from our streams during 1920.

The increased cost of mining coal and the profits accruing from the simple dredging operations just described are causing the mine operators to realize that the coal now wasted by the wet process breakers and by the washeries should no longer be discharged into the streams. Furthermore, the need for some method of treatment whereby mine water can be successfully used in the breakers, obviating the great expense of pumping non-acid water long distances or the present high replacement costs due to the corrosive action of acid water, is each year becoming more apparent. A general idea of the volume of water required at the one hundred or more anthracite breakers can be obtained when we consider that approximately one gallon of wash water is required a minute for each one ton of the daily coal output, and the damage due to use of acid waters in the breakers may be estimated from the statement that annual replacement and repair costs of twenty thousand dollars at a single large breaker are not unusual.

Within the past two years several plants designed to eliminate the present coal wastage have been installed in the anthracite region. The process is, essentially, separation of the fine coal by sedimentation and can be further developed by neutralization of the acid by lime treatment to render the mine water suitable for use in the breakers. The sedimentation tanks are of the radial flow type, and the effluent is discharged over a weir around the periphery. Slowly revolving, radial arms sweep the sedimented particles to a small discharge opening at the apex of the inverted cone forming the bottom. The fine coal thus removed from the basins is passed through mechanical concentrators or classifiers, similar to those in use in lead, zinc and copper mining. Operating results at one of these coal recovery plants will serve as an illustration of the general process. Slush, after being wasted by the finest screen of a modern wet process mine breaker, a screen having holes three-sixty-fourths of an inch in diameter, passes through the recovery

plant at a rate of about 3500 gallons a minute and yields approximately 150 tons of usable coal a day. The effluent of this particular sedimentation basin is freed of materials which would be retained on screens having sixty meshes to the lineal inch, or approximately one-half the total weight of suspended solids in the breaker slush. Other basins are designed and operated to remove all solids which would be retained on a one-hundred-mesh screen. If desired, the wastes from the first set of basins and the concentrating tables can be passed through secondary basins for removal of all readily settleable materials, producing a clear effluent. It should be stated, however, that materials removed by such supplementary sedimentation would be mostly silt and particles of coal too fine for present market purposes.

It has been estimated that universal installation of settling basins of the type described, or others similar in function, would increase the coal output of the anthracite region by about 3,000,000 tons annually. Such increase would not only represent substantial profits to the mine owners, but, to a very considerable degree, would reduce the conspicuous and damaging stream pollution of these regions.

A generation ago the development of this method of freeing breaker and washery wastes from the fine particles of coal in suspension would have had little value, for there would have been no market for the salvaged coal. The combustion engineers who developed practical methods for using powdered coal as a fuel, successful procedure for briquetting coal and improved design of mechanical stokers have paved the way for this process of coal conservation.

For the neutralization of the acid mine drainage to permit its use in the breakers of the anthracite region and for quenching coke in the bituminous fields, we can turn to a method in successful and profitable use in the western part of the State. A few years ago at one of the coke burning villages the supply of neutral water for quenching purposes was insufficient during droughts, and as all the streams in the vicinity were so contaminated with mine drainage that use of the water would discolor the coke and increase its sulphur content, thus materially decreasing its market value, the engineers and chemists of the mining company undertook the neutralization of the acid stream water with limestone to produce a

suitable water for use at the coke ovens, thus conserving the meagre supply of non-acid water in the reservoirs for domestic and power purposes.

These experiments have resulted in a plant which is treating upwards of one million gallons of mine water a day by addition of finely powdered limestone to neutralize the free sulphuric acid and to decompose the ferric sulphate into ferric hydrate. The sludge thus formed is removed by a sedimentation basin, similar to that described for removal of fine coal from drainage of the anthracite regions, and is then freed of excess moisture by a steam heated revolving dryer. The effluent water is sufficiently low in sulphur and iron to use for quenching coke and by virtue of the process the ovens at this mine have been operated during dry seasons when other mines in the vicinity were handicapped by a shortage of water. The dried sludge from the basins, containing ferric oxide, amounts to about seven tons a day and is in constant demand by manufacturers of artificial gas for use in removing the hydrogen sulphide present in such gas. It is stated that the revenue from this plant is materially in excess of the operating cost, thus furnishing the company with an additional water supply of approximately one million gallons a day at little or no expense. Experiments are now under way for a further development of this by-product, for example, as a substitute for the iron oxide in paint pigments and utilization of the phosphorus and potassium constituents in soil fertilization.

Even though feasible and profitable methods have been developed for removing the fine coal from the wastes of the anthracite region and for neutralization of the free acid of the wastes of both the anthracite and bituminous regions, we have not by any means solved the mine drainage problem. The enormous quantities of lime which would be required for neutralization of the acidity of drainage from all of the mines, together with the moderate market for the resulting product place limitations upon the wide adoption of this method. Furthermore, it is faulty in one essential feature, the effluent is not freed of the incrusting constituents and hence is not suitable for either boiler or domestic water supply purposes, even after passage through fine grained sand filters. It has previously been stated that some ninety-six water supplies of the State are now difficult of purification because of mine drainage pollution of the raw water, and this number is certain to grow as addi-

tional mines are opened, contaminating streams now free from acid drainage and increasing the contamination of streams at present receiving only moderate volumes of such drainage.

The most successful method yet devised for neutralization of acid mine drainage and for removal of the boiler scale forming constituents makes use of barium carbonate, which reacting on the sulphates formed by previous addition of lime, results in the relatively insoluble barium sulphate, which can be removed by filtration, giving a clear and soft water. At least three such plants are in operation in the west and are stated to produce a superior water for boiler purposes. Unfortunately, the barium salts are expensive and, of more consequence, they are poisonous. There is no absolute guarantee that the barium will always be entirely precipitated when used in treatment of a water contaminated by a combination of mine drainage with other wastes which are acid in reaction, especially in the event of accidental and unforeseen conditions of filter plant operation. Its use, therefore, for treatment of water intended for human consumption cannot be justified.

The absence of a satisfactory method for complete treatment of mine drainage is not because the problem has been neglected by able investigators, but rather is due to the fact that, in the past, studies have been directed at only a single aspect of the problem, and when the particular objective had been reached the search was abandoned.

This is equally true in the case of other industrial wastes; for instance, there have been studies to develop methods of treatment of certain wastes to prevent nuisance in the case of discharge into a large body of water, other studies to prevent destruction of fish life, and numerous others simply to recover single products of value which had been wasted.

Within the past few years various government departments and bureaus and the scientific staffs of large industrial establishments throughout the world have undertaken comprehensive studies of methods of disposal of many industrial wastes. The object of these studies has been two-fold: first, to recover products of value from the wastes, and second, in case such products did not exist or could not be extracted by any method known to science, to develop some economical process for modifying the wastes so as not to prevent any legitimate uses of the receiving body of water and to determine the limitations of the method of disposal selected.

Only since the inception of this class of investigations has real and definite progress been made.

The industrial prosperity of any State may safely be said to depend upon a suitable and adequate water supply. With the tendency to concentration of our industries, the local needs for such water supplies will increase, requiring even greater progress to be made in solution of industrial waste disposal problems. Investigations made thus far demonstrate that the goal can be reached only through refined methods of manufacture to make use of all possible elements of value in the raw materials and also methods of treatment which will recover all products of commercial value in the industrial wastes in order to partially or even wholly offset the cost of treatment of the portions which are without value.

Progress towards this end has been rapid and the future is bright. Therefore, it appears that the creation of nuisance in streams and the destruction of their usefulness through lack of proper disposal of industrial wastes has passed the peak, and that in a few years such improvements in the general condition of the surface waters of our industrial states will be obtained that they can be economically used for all legitimate purposes.

Action of Sodium Sulphide on Ferric Oxide.—By the reaction of finely divided ferric oxide with crystalline sodium sulphide, a black amorphous substance is formed. After the major portion of the sodium sulphide has been removed, the residual mass yields a brilliant green solution; the color is due to a colloidal iron compound which contains neither sodium nor sulphur in its molecule. The colloid is precipitated by a relatively large amount of sodium sulphide, also by complete removal of the sodium sulphide by either dialysis or oxidation. The green solution contains less than 0.07 gram iron per litre, and cannot be dialyzed in the presence of air. If air be drawn through the solution until the sodium sulphide is oxidized to sodium sulphate, the color of the solution changes to brown, apparently due to the formation of a colloidal hydrated ferric oxide which finally precipitates. (J. C. WITT in *Journ. Am. Chem. Soc.*, 1921, xliii, 734–740.)

J. S. H.

TIDAL OBSERVATIONS OFF THE ENTRANCE TO DELAWARE BAY.*

BY

H. A. MARMER.

Coast and Geodetic Survey, Washington, D. C.

Our knowledge of the time and range of the tide away from the coast is extremely meagre, since tidal observations have been confined almost wholly to the immediate vicinity of the coast. Any attempt, therefore, at presenting a comprehensive view of the tides, as for example that involved in the construction of a cotidal map of the world, is necessarily based on theoretical considerations upon which agreement is not yet unanimous. Hence all tidal observations made at some distance from the coast are of considerable value.

It is this that lends particular interest to a series of accurate tidal observations covering a period of 40 hours, made on the southern end of Five Fathom Bank (latitude 38° 50.7′ N, longitude 74° 37.8′ W), about 18 nautical miles east of the entrance to Delaware Bay on Sept. 28–30, 1920. These observations were made in connection with offshore precise dead-reckoning hydrography, by the party of the U. S. Coast and Geodetic Survey Steamer *Bache*, Capt. H. A. Seran, commanding.

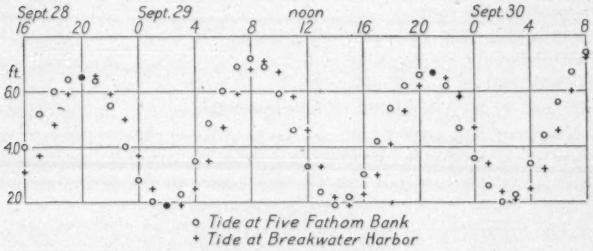
The apparatus used for measuring the rise and fall of the tide was a very simple one, but gave quite accurate results. It consisted of a tide staff, one inch square and ten feet long, secured to a float and confined in a two-inch pipe 33 feet long. The pipe was ordinary stock galvanized pipe made up in sections about twelve feet long, with the bottom section cast in an 800 pound block of concrete. To keep the pipe upright, it was moored by No. 6 galvanized wire to four concrete blocks weighing somewhat more than half a ton apiece, placed about 100 feet from the bottom of the pipe.

To eliminate wave motion it was decided to admit the tide near the bottom. But it was also necessary to place the opening

* Communicated by William Bowie, Chief, Division of Geodesy.

high enough to prevent clogging by sand or other matter. The opening was, therefore, made in the bottom section of the pipe about seven feet from its junction with the concrete base. The tide staff was graduated to feet and two-tenths, the figures increasing downward, so that the height of the tide was read directly at the top of the pipe. As arranged, the tide staff could be read from the ship at some distance from the tide gauge.

The height of the tide was read every hour and is here shown plotted on cross-section paper, the circles giving the hourly heights of the tide as read. The curve is seen to be the regular semi-daily tide curve. For comparison there is plotted the hourly height of tide (indicated by crosses) as read from an automatic tide gauge record operating simultaneously at Breakwater Harbor, Delaware, just inside Delaware Bay, and about twenty-three miles from Five Fathom Bank.



The range of the tide appears to be almost exactly the same as at Breakwater Harbor. For the period of observations at Five Fathom Bank the range was 4.9 feet, which reduced to a mean value by comparison with a long series of tidal observations at Breakwater Harbor, makes the mean range 4.3 feet.

From the simultaneous observations plotted here, the time of tide at Five Fathom Bank is 45 minutes earlier than at Breakwater Harbor. This is somewhat less than the time required for a free wave to travel the distance of twenty-three miles over the average depth of 8½ fathoms between Breakwater Harbor and Five Fathom Bank.

Based on these observations the cotidal hour for Five Fathom Bank is about XII.2. In this connection it is interesting to note that on the cotidal maps of the world, constructed by Dr. R. A. Harris,[1] the XII hour cotidal line is slightly to the west of Five Fathom Bank. In constructing the cotidal lines offshore, Doctor Harris was compelled to rely wholly on theoretical considerations, which in this case are well borne out by the tidal observations.

Manufacture of Aircraft, 1919.—A preliminary statement of the general results of the 1920 census of manufactures with reference to aircraft has been issued by the Bureau of the Census, Department of Commerce, furnishing a detailed statement of the quantities and values of the different types of aircraft manufactured during the year 1919, prepared under the direction of Mr. Eugene Hartley, Chief Statistician for Manufactures.

Reports were received from 31 establishments engaged in the industry during 1919, showing products for the year valued at $14,372,643, as compared with 16 establishments in 1914 with products valued at $789,872. Of the 31 establishments reporting for the year 1919, 10 were located in New York; 4 in Ohio; 2 each in California, Massachusetts, and Missouri; and 1 each in Connecticut, Indiana, Illinois, Louisiana, Maryland, Nebraska, New Jersey, Pennsylvania, Rhode Island, Washington, and West Virginia.

The following is a summary of statistics of the industry for 1919, the "All other products" reported consisting chiefly of airplane parts, engines, and repair work.

Summary of Statistics of the Aircraft Industry, 1919.

Number of establishments	31
Total value of products	$14,372,643
Airplanes:	
Number	432
Value	$3,466,452
Seaplanes:	
Number	230
Value	$4,580,016
Value of work done during year on airplanes and seaplanes not completed	$1,658,670
All other products, including parts and repair work	$4,667,505

[1] See Cotidal Lines of the World (Manual of Tides, Part IVB), by R. A. Harris, Washington, D. C. 1904.

Chemical Industry in the Argentine Republic.—Three Argentine companies manufacture sulphuric acid (53°–56° Baumé) by the chamber process with imported sulphur from Italy, Chile, and the United States. There is a great demand for Sicilian sulphur, being of greater purity, and burning without ash. Transport of sulphuric acid by sea is very difficult, owing to long voyages in the tropics, the home industry being thus favored. Nevertheless, local works find it difficult to compete with imports.

Nitric and hydrochloric acids, the first in commercial degrees (38 and 42), are manufactured from Chile saltpetre and native salt. Chemically pure sulphuric and hydrochloric acids are also manufactured. The main part of the acetic acid imported is glacial, at 99°. Two works near Cordoba produced pyroligneous products by dry distillation of algarrobo wood, chiefly lead and lime acetates, acetone and acetic acid, which are more expensive than imports. However, the demand exceeds the supply. Local production of tartaric acid is limited to one or two vineyards, wine-lees being obtained in large quantity at Mendoza. In 1916 the United States began to export this acid to the Argentine. During the last eight years imports of citric acid from France, England, Germany, and Italy, represented an average of 132 metric tons per year. The United States commenced exports in 1914. The acids sell better in crystals than powder. Imports of phenol are very irregular; England is the chief source. Tar oil acids are preferred for washing cattle. The oils should contain at least 10 per cent. phenol, and some manufacturers say 25 per cent. Boric, hydrofluoric, and tannic acids and carbon dioxide are also from Germany, France, England, and, since 1916, the United States has supplied a certain amount of carbon dioxide, which is also manufactured locally in breweries. Imports of alum, which were more than 6300 metric tons from 1913 to 1916 fell to 490 tons during the last two years. The United States imports now represent 50 per cent. Hydrated alumina is employed to a limited degree for lakes and colors, textiles and glass. Large quantities of home-made aluminum sulphate are employed to purify drinking water. Local manufacture is only one-quarter of the imports. Ammonia solution is chiefly imported. The average imports during the last seven years were 540 metric tons per year, 90 per cent. being from America Liquid ammonia is chiefly English. Arsenic and arsenical compounds are employed for glass, insecticides, and colors. The demand is for white, yellow, and red arsenic (99 per cent.), in barrels of 200 kilograms, and lead and sodium arsenates in boxes of 5 kilograms. The United States now heads the list of imports.—(*Chimie et Industrie*, through *Chem. News.*)

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

FIRE TESTS OF BUILDING COLUMNS.[1]

By S. H. Ingberg, H. K. Griffin, W. C. Robinson and R. E. Wilson.

[Abstract.]

This is an experimental investigation of the resistance of columns, loaded and exposed to fire or to fire and water, with a record of characteristic effects, conducted in coöperation with the Associated Factory Mutual Fire Insurance Companies and the National Board of Fire Underwriters, the tests being made at Underwriters' Laboratories.

Method and Scope.—The fire exposure was produced by placing the column in the chamber of a gas-fired furnace, whose temperature rise was regulated to conform with a predetermined time-temperature relation. Measurements were taken of the temperature of the furnace and test column and of the deformation of the latter due to the load and heat.

The test columns were designed for a working load of approximately 100,000 pounds, as calculated according to accepted formulas. The amount varying somewhat for the different columns. The working load was maintained constant on the column during the test, the efficiency of the column or its covering being determined by the length of time it withstood the combined load and fire exposure.

In the fire and water tests, the column was loaded and exposed to fire for a predetermined period, at the end of which the furnace doors were opened and a hose stream applied to the heated column, the severity of the test being regulated to correspond with the degree of resistance developed by the corresponding type of column in the regular fire tests.

The paper reports on 106 tests of columns, of which 91 were fire tests and 15 fire and water tests.

The series includes: (1) tests of representative types of un-

* Communicated by the Director.

[1] Technologic Paper No. 184.

protected structural steel, cast iron, concrete-filled pipe and timber columns; (2) tests wherein the metal was partly protected by filling the reëntrant portions or interior of columns with concrete; (3) tests wherein the load-carrying elements of the columns were protected by a 2-inch or 4-inch thickness of concrete, hollow clay tile, clay brick, gypsum block, and also, single or double layers of plaster on metal lath; (4) reinforced concrete columns with 2-inch integral concrete protection.

The covering materials for each class of protection were obtained from the main producing regions of the country, the object being to include samples from the principal mineralogical subdivisions that find general application in building construction. A large number of auxiliary tests of constituent materials were made, which are described and results given in a separate section with the aid of diagrams and 30 pages of tabulations, forming a fairly comprehensive source of information on the physical and chemical properties of the materials used in modern fire-resistive construction.

In placing the columns and coverings, the work was planned so as to reproduce as nearly as possible the conditions obtained in building construction, in point of methods of application and workmanship. This was done to make the results of the tests applicable without undue allowance for differences that otherwise might be deemed to exist between the test column and a similarly constructed member in a building.

Test Results.—These are presented in 12 tables and 128 figures and diagrams, the latter comprising views of columns before and after test, the time-temperature curves for the furnace and 6 to 12 points on the test column, and unit deformation with corresponding average column temperature curves. Test logs give detailed developments during each test.

The results in point of time to failure in the fire test are studied with reference to size of column, and for given column and covering materials, relations are established between fire resistance and area of solid material in the column cross section. The test results, supplemented by investigations on the properties of the column materials under heat and load, also afforded means for determining the useful limit of a column when loaded and exposed to fire. A summary of general characteristics of the column and covering materials, as developed in the fire tests and

the auxiliary tests, is made, which can in part be applied to building members other than columns. A summary is given of methods used and results attained in previous investigations and an effort made to interpret the latter with the aid of the information now available.

Fire Resistance Periods.—The results of the tests are finally summarized in terms of hours and minutes of fire resistance afforded by the different types of columns and protections tested. The resistance period is taken as a portion (two-thirds) of the average time to failure in the fire tests, the deduction being made to allow for incidental variations in material and workmanship of columns and coverings as tested and as installed in buildings and also for differences in load and fire conditions that cause variations in results with nominally comparable columns. Requirements relative to resistance to water application are limited to ability to sustain load without danger of immediate collapse in case of fire recurring after fire and water exposure. Application of the results is extended beyond the particular materials tested as far as existing knowledge of the properties of related materials justifies it, this being done to give the results greater continuity, Interpolation is also made for a covering thickness intermediate between those tested.

The resistance periods thus derived vary from 10 minutes for unprotected structural steel columns to 8 hours for similar columns covered with 4-inch thickness of concrete made with fire resistive aggregates and reinforced concrete columns made with the same aggregates. Filling the reëntrant portions or interior of structural steel columns with concrete gave them resistance periods ranging from ½ hour to 3½ hours, depending on the size and shape of the column and the concrete aggregates employed. Single-layer protection of plaster on metal lath applied to structural steel columns gave ¾-hour resistance, and double layer, with airspace between layers, 1½ hours. Two-inch concrete protection on structural steel columns gave resistance periods from one hour to four hours, depending on the aggregate employed. The concrete made with sand and pebbles high in silica (chert and quartz) developed disruptive effects on exposure to fire, which is ascribed (1) to points of abrupt volume change existing for chert as low as 210° C. and for quartz at 573° C. where it is transformed into the mineral tridymite; (2)

to disruption of the pebbles from evaporation of the chemically combined water of the chert, and water occluded in tiny cavities in the quartz when it crystallized. Concrete made with trap rock, granite, sandstone, or hard coal cinder aggregate proved superior to that made with siliceous gravel. The highest resistance obtained with concrete made with dolomitic limestone and calcareous sand. The 4-inch concrete protections developed resistance periods from 2½ to 8 hours, the variation with the aggregate being similar to that for the 2-inch protections.

Hollow clay tile on structural steel columns gave periods from one hour to 3 hours, depending on the type of clay and method of application. Tile made from semi-fire clay burnt to medium hardness developed greater freedom from cracking and spalling than any other tile tested. Hard burnt semi-fire clay tile evidenced greater effects from fire exposure, and with surface clay and shale tile these disruptive effects were very marked. Little or no difference in resistance was noted as between the 2-inch and 4-inch thickness of hollow tile, the time to failure being dependent on the area of solid material rather than on the thickness of the air space. Filling the interior with concrete or tile appreciably increased the resistance and stability of the covering, and interior metal ties were found to be superior to outside wire ties in holding the tile in place. Solid clay brick set on end and edge to form a solid covering about 2½ inches thick outside of the steel proved somewhat unstable on exposure to fire and developed a resistance period of only one hour, while with brick laid flat in the usual manner to form a 4-inch covering thickness, 5-hour fire resistance was developed. Solid gypsum block, 2 inches in thickness, laid outside of flanges and edges of structural steel columns and with space between blocks and flanges filled with gypsum mortar, gypsum blocks, or poured gypsum filling, gave 1½-hour resistance, and similar coverings made with 4-inch solid blocks gave 3½-hour resistance, the failure being due in all cases to shrinking, checking, and disintegration of the blocks which caused them to fall off and expose the steel.

Round hollow cast iron columns developed 20-minute fire resistance as tested unprotected, and ½-hour resistance when unprotected and filled with concrete. Protections approximately 2 inches in thickness and consisting of Portland cement plaster on metal lath, hard coal cinder concrete, or round porous semi-

fire clay tile increased their resistance period to 2 hours. Steel or wrought pipe not smaller than the 6-inch standard size, filled with 1:4½ concrete gave resistance period of 25 minutes and similar pipe, not smaller than the 7-inch standard size, filled with concrete and reinforced in the fill with structural angles, gave ¾-hour resistance.

Reinforced concrete columns with 2-inch integral concrete protection, gave 5-hour resistance as made with trap rock aggregate, and 8-hour resistance as made with limestone aggregate.

Pine and fir timber columns with unprotected cast iron or steel caps gave 25-minute resistance, with column and cap covered with ⅜-inch gypsum wall board gave ¾-hour resistance, and with protection of Portland cement plaster on metal lath gave 1½-hour resistance. The cause of failure of the timber columns was loss of strength of the wood at the cap bearings due to conduction of heat from the flanges of the metal caps to the bearing plates and into the wood, which caused it to soften, crush, and induce slipping or fracture of the caps. While the fire test reduced the area of the columns by 29 to 55 per cent., their resistance to fire and load outside of the bearings was not fully developed in the tests.

The series fairly covers the range of current practice in structural steel columns and perhaps also, in proportion to the extent of their use, in that of the other column materials except reinforced concrete, which latter is the subject of a special investigation recently completed by this Bureau. The studies made on effect of size indicate that the results obtained with the columns tested, which were representative of the smaller sizes in general use, can be extended with safety to larger columns.

THE WAR WORK OF THE BUREAU OF STANDARDS.*

[ABSTRACT.]

IT has seemed advisable to gather together in one report descriptions of some of the more important military investigations conducted by the Bureau of Standards during the war. This is important for two reasons. In the first place it is essential that as complete a record as possible be kept of the activities of the Bureau

* Miscellaneous Publication No. 46.

during the period of hostilities; and in the second place, many of the results gained through military investigations are equally applicable and important in peace-time work.

The report consists of short descriptions of the various investigations which were carried out, each description being complete in itself and having no reference to the organization of the Bureau or the scientific divisions which carried out the work. It is, therefore, possible to read any one of the sections of the report without referring to any of the others. No attempt has been made to give complete descriptions, and but little data will be found as it was believed better to limit the text of this report to general information and conclusions.

Detailed results of the various military investigations which the Bureau conducted will be found not only in the regular publications of the Bureau of Standards, but in the reports and specifications of the War and Navy Departments, and in the material published by such organizations as the National Advisory Committee for Aeronautics. In almost all cases the Bureau's war work was carried out in close coöperation with these other organizations, and quite frequently the Bureau itself issued no reports on the subject.

A very large number of subjects will be found to be treated, a few of which are as follows: Aeronautic instruments; aeronautic power plants; aircraft materials and construction: such as the relative merits of wood and metals for building airplanes, the best substances for airplane dopes, etc.; balloon gases, including the work which the Bureau performed in connection with the recovery of helium from natural gas; the calibration of testing machines, by which the tests made at various arsenals and munitions plants were referred back to the standards of the Bureau; various chemical investigations, including analyses of ferrous and nonferrous metals, the development of platinum substitutes, the routine testing of soap, oils, and paints, experiments in connection with the prevention of corrosion, etc. Chromatic camouflage and its detection illustrates the application of scientific work in optics to modern warfare, while the description of the investigation of various processes for coking inferior grades of coal illustrates the successful coöperation of the Bureau with other Government establishments, in this case the Bureau of Mines.

In connection with the building of concrete ships, a new aggre-

gate giving a particularly light and strong concrete was developed. Other parts of the report deal with various electrical subjects, such as batteries for automobiles and trucks, electric generators for setting off high explosives, magnetic methods for detection of flaws in steel, testing of special lamps for signalling purposes, and extremely important work in connection with radio telegraphy and telephony, including the development of the radio direction finder, radio instruments for submarines and the electron tube.

The production and testing of precision gages in various munitions plants was one of the important pieces of work conducted by the Bureau and will be found to be briefly described.

Various materials of construction, ranging from metals to leather and rubber, were tested in large quantities and investigations conducted to determine their availability for all sorts of new uses. This work, as well as the more usual testing of structural materials, will be found described in the report.

In connection with the development of various new processes of manufacture in the United States, mention should be made of the work on the production of optical glass, the making of a successful cotton fabric for airplane wing construction to replace linen formerly employed, and aid in the development of a satisfactory laminated wood construction for airplane beams. Many other subjects are included in the report, but the above list is typical.

Illustrations are given showing the apparatus employed in some of the investigations and also various representative specimens, ranging from simple devices to complicated machinery, which were tested by the Bureau.

OSCILLOGRAPH MEASUREMENTS OF THE INSTANTANEOUS VALUES OF CURRENT AND VOLTAGE IN THE BATTERY CIRCUIT OF AUTOMOBILES.*

By George W. Vinal and C. L. Snyder.

[ABSTRACT.]

THIS investigation was begun to study the demands upon starting and lighting batteries in the operation of various types of automobiles. For some months the Bureau of Standards has been working upon specifications for starting and lighting batteries at

* Technologic Paper No. 186.

the request of the Motor Transport Corps of the War Department. These specifications have now been completed, but it was thought desirable to obtain additional information about the performance of batteries when in actual use on automobiles, to supplement the tests which have been made in the laboratory. By using the oscillograph, photographic records of the current and voltage have been obtained. These photographs show the instantaneous values of current and voltage which cannot be obtained by using the ordinary indicating instruments. The results obtained indicate that at the instant when the starter switch is closed the current delivered by the battery on various cars is higher than has generally been supposed, and that it depends very largely on the inertia of the system. After the starter has begun to turn, the current decreases rapidly, pulsating with the compression in the successive cylinders. Typical records are given for a few of the various makes of automobiles that have been measured. In the course of the experiments additional information was obtained with respect to the operation of the starter system and the engine itself. The results given are intended to be suggestive rather than quantitative measurements of performance. They indicate the possibility of using this method for the study of problems relating to lubrication, ignition, compression, distributor action and changes in fly-wheel velocity. In addition to studying the discharge of the battery, oscillograms were also obtained of the charging current when the engine was running. Measurements were made at several different temperatures and curves showing the effect of relieving the compression by removing the spark plugs are also given. The characteristic curves of five different makes of cars are shown. These cars were in ordinary running condition at the time the measurements were made.

DISCUSSION OF THE NATIONAL ELECTRICAL SAFETY CODE.*

[ABSTRACT.]

THIS handbook contains the revised discussion of the National Electrical Safety Code and forms a companion volume to Handbook No. 3, which contains the revised edition of the rules them-

* Handbook No. 4.

selves. The discussion of the rules has been considerably amplified. Many items and suggestions have been included which are not involved in the rules themselves, but which have bearing upon good practice and matters immediately related to the subject of the rules. In addition the endeavor has been made to make the meaning and interpretation of the rules entirely evident and to give in many cases the reasons which have prompted inclusion of particular rules in the Electrical Safety Code. Illustrations have been provided to show the intent and application of a number of rules.

The discussion of the rules follows the order of the rules themselves and is segregated into the four parts dealing respectively with stations and substations, overhead and underground lines, utilization apparatus, and operation of utility stations and lines. There is also a supplementary section dealing with the subject of grounding. The introduction to the discussion includes the results of a survey of pole lines made jointly with the committee on safety rules of the National Electric Light Association in the summer of 1919.

Exchange Professors in Engineering and Applied Science.—There has been for some time a regular annual exchange of professors between individual universities in France and America in regular academic fields, such as literature, history, law, fine arts, economics, etc., but there has never been, as yet, any such exchange in engineering or applied science. These subjects are taught in France by special faculties, not included in existing exchanges with America. Furthermore, the French methods of teaching these subjects are unlike our American methods, for various reasons, based on the history, traditions and sociology of the two countries. The great war showed the importance of engineering in production and distribution, and the many ties of friendship which bind us to France, depend in various ways upon applied science. It should therefore, be of mutual advantage to become better acquainted with each other's ideals and viewpoints, in the study and in the teaching of these great groups of subjects.

With these purposes in mind, the late Dr. R. C. Maclaurin, in 1919, as President of the Massachusetts Institute of Technology, consulted the presidents of six universities on or near the Atlantic seaboard, as to whether they deemed it desirable to coöperate in such a joint exchange of professors with France, on a plan definitely outlined. Their replies being very favorable to the project, a committee was appointed, with one member from each of the seven institutions, to report on the plan, and on methods

of carrying it into effect. The committee met in December, 1919, and ratified the coöperative plan with some few modifications. The present president of the committee is Director Russell H. Chittenden, of Yale, and its secretary Dean J. B. Whitehead, of Johns Hopkins.

Since the Institute of International Education, in New York, concerns itself with the interchange of college students and teachers from all parts of the world, the committee requested the Institute's director, Dr. Stephen P. Duggan, to undertake the negotiations between the committee and the French University Administration. The result has been that the French Administration responded very cordially to the offer for the annual exchange of a professor. The French have selected, for their first representative, Professor J. Cavalier, rector of the University of Toulouse, and a well known authority on metallurgical chemistry, to come to America this fall, and to divide his time during the ensuing academic year, among the seven coöperating institutions, namely, Columbia, Cornell, Harvard, Johns Hopkins, Massachusetts Institute of Technology, Pennsylvania and Yale. Although it would have been impracticable to have included a larger number than seven in the American plan, yet it is hoped that other institutions may also derive benefit from the incoming French professor's visit.

The American universities have selected as their outgoing representative for the same first year (1921–22), Dr. A. E. Kennelly, professor of electrical engineering at Harvard University and the Massachusetts Institute of Technology.

If the plan continues to operate as favorably as it has commenced, there should not only be a steady annual exchange of a professor, in these various branches of applied science, but also a steady interchange of advanced students between France and America, in these same fields, to the increase of mutual study, mutual teaching and mutual friendship.

Melting Point of Diphenylamine.—Since diphenylamine is used extensively in the explosive and dye industries, it has become a product of commercial importance. Its melting point is usually given as 54° C. A redetermination of the melting point has been made by Homer Rogers, W. C. Holmes, and W. L. Lindsay (*Journ. Ind. and Eng. Chem.*, 1921, xiii, 314–316), using thoroughly purified diphenylamine and standardized thermometers. Two separate series of experiments gave 52.96° C. and 53.00° C., respectively, as the melting point. Therefore, the value, to the nearest tenth of a degree, is 53.0° C.

J. S. H.

NOTES FROM NELA RESEARCH LABORATORY.*

EFFECT OF STRONG ELECTROSTATIC FIELDS ON THE VAPORIZATION OF TUNGSTEN.

By A. G. Worthing and W. C. Baker.

THE general procedure has consisted in noting the rate of change of resistance of a tungsten filament operated in vacuo at some fixed current; first, when exposed to a weak electrostatic field opposing thermionic emission; and second, when exposed to a similarly directed strong electrostatic field. For well-seasoned filaments, the changes in resistance with continued burning, at least for moderate electrostatic fields, are due largely to changes in filament cross section resulting from vaporization. Therefore, any difference in the rate of change of resistance for the two conditions of operation is naturally to be ascribed to the effect of the strong electrostatic field on the rate of vaporization of the material.

The most satisfactory mounting for the filaments studied contained two insulated circuits leading through the stem of a well-evacuated, hard-glass lamp bulb. One of these circuits included the filament to be investigated held straight and taut by springs of larger tungsten wire, in axis of a helical coil of still larger tungsten wire which formed a part of the other insulated circuit. All wires leading into the lamp bulb, as well as all wires within, were of tungsten. All junctions were fused. The strong electrostatic field was obtained by connecting the insulated coil to the negative terminal of a small motor-driven Wimshurst machine while the hot filament and the frame of the machine were earthed.

In the most satisfactory test conducted, a 0.060 mm. filament 3.5 cm. long, mounted in a 6 mm. helix 3.2 cm. long, was operated at 2780° K alternately for several time intervals of equal length, first, with a potential difference between filament and coil of 30 volts, and second, with an average potential difference of 11,000 volts. This latter value corresponded to an electrostatic field strength of 800,000 volts/cm. at the surface of the filament.

The measured resistance platted as functions of time of burning showed a straight line relationship for each interval of burn-

* Communicated by the Director.

ing. The averages of the slopes, four against three, showed no change to within one-half per cent. due to electrostatic field. Hence, we conclude that, for the conditions specified, the effect of the electrostatic field on the vaporization of tungsten is negligible.

According to generally accepted views a filament connected to earth becomes deficient in negative electrons when exposed to a steady negative electrostatic field. This means that there exists in the filament an excess of positive ions during the continuation of the electrostatic field. These are probably located on the surface and may here be called "surface ions" to distinguish them from the very temporary ions throughout the filament which are the counterparts of the temporary free electrons. A field strength of 800,000 volts/cm. mentioned above, means a "surface ion" density of 44×10^{10} ions/cm.,^{2} one atom of every 70,000 surface atoms being ionized.

Due to the pull of the electrostatic field these positive "surface ions" might be expected to be more easily detached, that is to be more readily vaporized than neutral surface atoms. Just what forces are called into play and how they are directed is difficult to say since we have no way as yet of determining whether these "surface ions" sustain the whole or only a part of the pull of the electrostatic field on the filament. Thus (1) the tubes of induction from the coil may terminate only on surface ions; (2) the tubes may terminate indifferently on neutral atoms and surface ions, with a readjustment of the tubes within and between the atoms of the filament; or (3) the tubes may congregate in bundles with relatively a large portion of them terminating on "surface ions," and with the remainder terminating on neutral atoms, but with a selective tendency for atoms in close proximity to "surface ions." On supposition (1) the "surface ions" sustain the total pull due to the electrostatic field; on supposition (2) the pulls sustained by a surface ion and a neutral atom are equal; on supposition (3) the pull sustained by the "surface ions" is intermediate between those sustained in cases (1) and (2).

Supposition (3) seems most probable. Some speculation on the basis of (1), however, is perhaps permissible, since in that case the computations, in addition to entailing only a moderate amount of labor, will likely give some idea of the magnitudes of the actual electrostatic forces to which the "surface ions" are subjected. For a field strength of 800,000 volts/cm., the pull on

an ion in a moderately smooth filament surface is computed to vary from about 63×10^{-5} dynes to roughly twice that amount, depending on how far out the individual ion may be from the surface described by the remaining "surface ions." This force is of the magnitude of the force computed from the estimated yield stress for a tungsten wire at incandescence reduced to a single atom (yield stress ÷ cross-sectional surface density of atoms). This approximate coincidence, together with the failure to detect an effect of an electrostatic field on vaporization, does not necessarily indicate any error in supposition (1) or in the computations made, since, on the "amorphous phase theory" of the binding material between grains the yield stress may depend on the weak amorphous phase while the resistance to vaporization depends largely on the cohesive forces within the crystal. Moreover, vaporization takes place by atoms, whereas the yielding of a stressed wire takes place by layers or "en bloc." On the other hand, the approximate coincidence leads us to hope that, by increasing the field strength, or by a modification of conditions, a positive influence of electrostatic fields on vaporization may be found.

CLEVELAND, OHIO,
November, 1920.

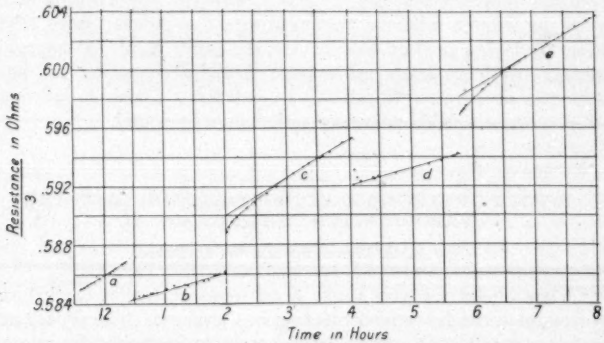
EFFECT OF STRONG ELECTROSTATIC FIELDS ON THE VAPORIZATION OF TUNGSTEN. II.

By A. G. Worthing and W. C. Baker.

THIS abstract covers work done in continuation of that reported on at the November meeting in Cleveland. The procedure, unchanged except in minor details, consists in noting the rate of increase in resistance of an incandescent filament in vacuo, first, when in a weak electrostatic field such as to prevent thermionic emission, and second, when in a strong field similarly directed. A difference in the two rates of increase is taken as evidence that vaporization is influenced by electrostatic fields.

In the work previously reported, a field strength of 800,000 volts/cm. at the surface of the filament, resulted in no appreciable change in the rate of increase of resistance with time. Since then improvements in the kenotrons, principally the reduction in filament diameter from 0.060 mm. to 0.020 mm., have resulted in considerably greater field strengths, the maximum being about 3.2×10^{-6} volts/cm.

The variation of resistance with time during a test, in which a field strength of 2.7×10^6 volts/cm. and a filament temperature of 2500° K were employed, is shown in the accompanying figure. The filament was operated throughout at 0.100,000 ampère. A steady temperature distribution was obtained after two hours of preliminary burning. Voltage readings were begun at 11 hr. 38 min. At 12 hr. 23 min. the strong electrostatic field was applied, at 2 hr. 0 min. it was removed, etc. With one exception, the variations shown are typical of those found in each case for field strengths above 1×10^6 volts/cm. Continued operation of the filament under each of the two conditions of burning led to a straight line relation between voltage and time, and hence also between filament resistance and time. Each change from a strong



Effect of strong electrostatic fields on the vaporization of tungsten II.

to a weak field caused a sudden increase in voltage readings, followed by a rather slow asymptotic change superposed upon the final straight line change with respect to time. Reverse changes, though less evident, occurred when the strong field was applied.

A positive effect of the electrostatic field on the rate of vaporization is shown in the figure by (1) the change in slope from 2.55×10^{-3} ohms/hr. for the weak field to 1.15×10^{-3} ohms/hr. for the strong field and (2) the lateral shifts in the straight lines representing the resistance changes after prolonged burning in the weak field. These effects diminished with diminishing field strength in such a manner as to indicate the practical disappearance of the effects at somewhat less than a million volts per cm.

On the other hand, test with one kenotron—the one used in obtaining the data shown in the figure—with a field of 3.2×10^6 volts/cm. showed neither of the two positive indications noted above; even though, when the strong field was applied or removed, the sudden and the slow asymptotic changes were more evident than when the lower field strengths were employed.

Work on this problem is being continued.

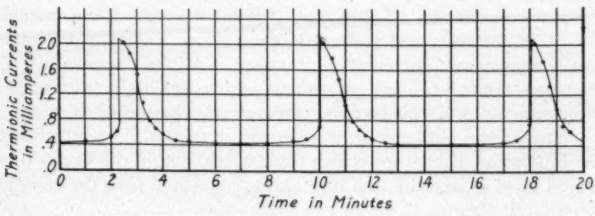
CLEVELAND, OHIO,
December, 1920.

PULSATING THERMIONIC DISCHARGES IN EVACUATED TUNGSTEN LAMPS.

By A. G. Worthing.

THE starting point of this investigation has been the observation of peculiar, periodic, automatic changes in brightness of a certain tungsten ribbon filament in an evacuated lamp bulb. Several other lamps were investigated only a few of which showed similar discharges, and none to the extent shown by the one in which the discovery was made.

All of the lamps tested contained a third insulated terminal by means of which thermionic discharges in the lamp could be



Pulsating thermionic discharges.

measured. Simultaneous observations of thermionic currents and of filament brightnesses by means of an optical pyrometer showed conclusively that the original variations noted in the filament brightness were directly connected with changes in the thermionic discharges in the lamp. These discharges may take place either from the filament to the insulated terminal, or from one leg of the filament to the other.

The tungsten ribbon filament in the lamp tested was V-shaped, with sides about 2.5 cm. long and with an apex slightly truncated so as to give an approximately square surface 1 mm. on edge, which in the mounting faced the third terminal, also of tungsten. The lamp was evacuated in the ordinary manner.

In one test, a direct current of 8.2 ampères was used in heating the filament to a temperature of about 2280° K. The negative terminal of a 44-volt battery was connected to one of the leads to the ribbon filament through a voltmeter with 5000 ohms resistance; the positive terminal of the battery was connected to the insulated terminal in the bulb.

The thermionic currents represented by the voltmeter readings showed discharges of a pulsating character (see accompanying figure) in which without any alteration of conditions by the experimenter, the currents rose from a moderately steady minimum, at first slowly and then with great suddenness, to a maximum value at least 4.8 times the minimum value. The period of the discharge, eight minutes, was constant for nine successive intervals to within 4 per cent. Small characteristic variations in the form of the curves were repeated also.

Different temperatures of operation, different applied voltages and resistances in the voltmeter circuit, yielded discharges differing in period, minimum and maximum current values, and ratios of maximum to minimum current values. Temperatures beyond a certain value and resistances below a certain minimum in the thermionic current circuit, other conditions remaining unchanged, tended toward pulsations which gradually diminished in intensity and disappeared, leaving a steady thermionic discharge.

No definite explanation is offered for this action. However, the blue glow discharges which were obtainable in the lamps used would seem to indicate that it might be connected with the residual gases in the lamps.

CLEVELAND, OHIO,
November, 1920.

THE CURRENT TEMPERATURE RELATION FOR DIFFERENT PYROMETER FILAMENTS.

By W. E. Forsythe.

THE calibration of a disappearing filament optical pyrometer is a determination of a relation between the temperature of the standard source and the current through the pyrometer filament,

when the latter is matched in brightness. For ease in reading temperatures against the standard, the current change for a particular temperature change should be as large as possible. It has often been stated that carbon pyrometer lamps were better than tungsten, because carbon at low temperatures gives a more open scale than the tungsten.

A test of this current temperature relation was made for a temperature range from 950° K to 1800° K. It was found that, if both the tungsten and the carbon pyrometer filaments were long enough so that the cooling due to end conductions were negligible, the ratios were about the same for the two.

The ratio of the currents for a hairpin tungsten filament, length of loop 12 cms., was 4.2 for a temperature range from 1828° K to 950° K; the ratio for a carbon hairpin loop 10 cms. long was 4.5 for the same temperature range. Both filaments were long enough so that the end effects could be neglected.

Development of Autochromes. (*Photographic Jl. of Am.*, April, 1921, p. 155.)—In spite of the many methods for color-photography that have been devised, the autochrome constitutes the simplest and most satisfactory in many lines, especially in photomicrography. The development of the plate was at first a tedious and troublesome process, and all the more unsatisfactory because of the tenderness of the film, which caused the loss of many a picture. Two features of the development were somewhat irritating; the prescription of a special chemical, "metoquinone," sometimes called "quinomet," and the use of an acid permanganate as an oxidizing agent. The latter is liable to form flocculent manganese dioxide, which deposits on the plate. The writer had a very pretty plate injured in this way. A solution of potassium dichromate and sulphuric acid is much better for oxidizing purposes. It can be prepared very strong, and diluted when used. It keeps indefinitely, and is cheaper than the permanganate solution. The special developer which figured in all the Lumière formula, was suspected by most photographers to be merely a mixture of our familiar dark-room twins, metol and hydroquinone, and this is now known to be the case.

Lumière Brothers have stated that instead of their "metoquinone," a mixture of metol and hydroquinone in the proportion of 10.5 parts of the former to 4.5 parts of the latter can be used. Victor Cremier states in "*Photo-Revue*" that the proportion of 7 parts of metol and 8 parts of hydroquinone gives excellent results. This is preferable, as metol is so much more costly than the other substance. Adopting Cremier's modification of a formula, given by Lumière Brothers, the

following is a formula taken from a recent issue of the "*Photographische Chronik*":

Water	1000 c.c.
Metol	7 gm.
Hydroquinone	8 gm.
Sodium Sulphite, dry	100 gm.
Ammonia (sp. gr. 0.923)	32 c.c.
Potassium Bromide	6 gm.

For use, dilute with four volumes of water.

The following developer was proposed about the time that the autochrome came into use:

Water	1000 c.c.
Sodium Sulphite, dry	40 gm.
Metol	6.5 gm.
Hydroquinone	2 gm.
Hypo.	0.1 gm.
Ammonia (sp. gr. 0.880)	20 c.c.
Potassium Bromide	2.5 gm.

For use, dilute with an equal volume of water.

For some lines of work, especially photomicrography, the second development may be omitted. Given a good exposure and a good first development, the oxidizing agent is then applied until the silver deposit is completely removed. The plate is then washed and dried. The unchanged silver bromide will act as the opaque coating, upon which the correct color effect depends.

Striking effects can be obtained by the use of autochromes in photographing the colors produced by the transmission of polarized light through rock section.

Melting Point of Ammonium Sulphate.—James Kendall and Arthur W. Davidson of Columbia University (*Journ. Ind. and Eng. Chem.* 1921 xiii, 303–304) have found the melting point of *acid* ammonium sulphate to be 146.9° ± 0.5° C., and the melting point of *neutral* ammonium sulphate to be 513° ± 2° C. The extreme discrepancies in the literature concerning these melting points were found to be due essentially to the instablity of the neutral salt when heated in an open tube.

J. S. H.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

PHOTOMETRIC METHODS AND APPARATUS FOR THE STUDY OF COLLOIDS.[1]

By S. E. Sheppard and Felix A. Elliott.

[ABSTRACT.]

Two types of apparatus are described intended for the study of suspensions or any finely divided systems. The underlying principle of the apparatus is the formation of two beams of light from the same light source. One of these beams is passed through the sample to be tested while the other, after passing through a wedge which controls its intensity, is brought into contiguity with the first beam by means of a photometric cube, and an intensity match is made.

In the first type of the apparatus all elements and beams are in the same horizontal plane. This form is particularly adapted to the measurement of the turbidity or clarity of solutions.

The second type of the apparatus has the optical system in the vertical plane. The standard and unkown solutions are interposed in the two light beams and may be compared as to color, light scattering power, clarity and by means of these measurements phases changes and quantitative determinations of the concentration of either phase may be made. This second type of the apparatus is readily convertible into a colorimeter of the usual type, a nephelometer, a scatter photometer, a mircro-photometer and a dispersimeter.

The dispersimeter is in itself a new instrument and is intended to measure dispersity. Concretely this is illustrated by considering an etched steel surface of which it is desired to estimate the relative areas of the etched to unetched constituents. An image of this steel etching is observed along side of an image of some standard dispersity, such as a halftone screen. In this screen we know accurately the ration of black to white space. The image of the standard screen is now enlarged until its pattern matches that of the steel. By dividing the enlargement of the steel image by the magnification of the standard screen or pattern the dispersity is accurately specified. The instrument has many practical uses.

* Communicated by the Director.

[1] *J. Amer. Chem. Soc.*, **43**, 531, March, 1921, Communication No. 106, from the Research Laboratory of the Eastman Kodak Company.

Dissolved Gases in Glass. WASHBURN, FOOTITT & BUNTING. (*Bulletin No. 118,* Engineering Experiment Station, University of Illinois.)—One of the difficulties encountered in the manufacture of glass is the prevention of small gas bubbles in the finished product, which are technically known as "seed."

The occurrence of these bubbles is due to the process of manufacture and is practically unavoidable, to a small extent at least, with ordinary methods. While for many purposes, provided that the bubbles are not too large or too numerous, the matter is of minor importance, there are other cases where it is most desirable to have a glass absolutely free from seed.

The bulletin deals with certain experimental work carried on at the Engineering Experiment Station of the University of Illinois with the object of discovering, if possible, a method by which a glass free from this defect might be produced.

The experiments described are to be regarded as preliminary to a more extended investigation, but have already demonstrated that even apparently clear glass may contain a considerable quantity of dissolved gas, which is the factor instrumental in producing seed. In addition, as a result of the experimental work, a convenient apparatus for measuring and analyzing the dissolved gases was developed, and an improved type of vacuum furnace for the manufacture of gas-free glass, which it is believed is capable of commercial application, was constructed.

The Phosphate-Rock Industry.—The phosphate-rock industry in the United States in 1920, according to figures from all producers compiled early in April by the United States Geological Survey, made a record far surpassing that of any previous year. The quantity of phosphate rock mined and sold was 4,103,982 long tons, or nearly a million tons more than in the record year 1918. The total receipts from sales was $25,079,572, or more than twice as much as in any other year. The average price per ton for the entire output was $6.11, as compared with $5.10 in 1919.

Florida's output more than doubled, the quantity of land pebble phosphate increasing by more than one and one-half million tons. South Carolina produced 27 per cent. less than in 1919, but Tennessee increased her output 100.000 tons, or 18 per cent. A most notable feature of the year was an increase of 223 per cent. in the production in Idaho and Utah. The western output, most of which was made by Idaho, increased from 17,000 tons in 1919 to more than 55,000 tons in 1920.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

STUDIES ON THE DIGESTIBILITY OF PROTEINS IN VITRO.

I. THE EFFECT OF COOKING ON THE DIGESTIBILITY OF PHASEOLIN.[1]

By Henry C. Waterman and Carl O. Johns.

[ABSTRACT.]

EXPERIMENTS to explain the findings of Johns and Finks [2] that phaseolin gave better results in feeding experiments after cooking than did the raw protein indicate that phaseolin is rendered more readily digestible by boiling with distilled water. Cooking for 5 minutes gave a delectable increase in digestibility, while cooking for ¾ hour was apparently sufficient to produce the maximum effect. It would seem therefore that the better results obtained after cooking may be considered to be due to an increase in digestibility.

STUDIES IN NURITION. V. THE NUTRITIVE VALUE OF SOY BEAN FLOUR AS A SUPPLEMENT TO WHEAT FLOUR.[3]

By Carl O. Johns and A. J. Finks.

[ABSTRACT.]

BREAD made with a mixture of 25 parts of soy bean flour and 75 parts of wheat flour contained a protein mixture and water soluble vitamines adequate for normal growth. A similar bread containing 15 parts of soy bean flour and 85 parts of wheat flour likewise furnished adequate proteins and water-soluble vitamines for normal growth.

These mixtures of the soy bean and wheat proteins were found two or three times more efficient than the proteins from wheat alone.

* Communicated by the Chief of the Bureau.

[1] Published in *J. Biol. Chem.*, 1921, **46**: 9.

[2] Published in *J. Biol. Chem.*, 1920, **41**: 379.

[3] Published in *Am. J. Physiol.*, 1921, **55**: 455.

THE USE OF EDESTIN IN DETERMINING THE PROTEOLYTIC ACTIVITY OF PEPSIN.[1]

By Joseph F. Brewster.

[ABSTRACT.]

THE United States Pharmacopœia method is the only official one in the United States for the assay of pepsin. This method is not proving satisfactory. Edestin, the protein of hempseed, has been used to supply the protein in clinical methods worked out by others for the determination of proteolytic activity, and since it is easily and cheaply prepared the author considers that it may advantageously be used in the assay of commercial pepsin.

Edestin is prepared by extracting nearly fat-free hempseed meal with 5 per cent. sodium chloride solution at 65°. The edestin, which separates on cooling the filtered extract, is recrystallized from the same medium. The nitrogen content of the washed and air-dried edestin is carefully determined, and this multiplied by 5.35 is adopted as giving the percentage of edestin in the preparation. From this the amount of preparation to supply a given amount of edestin is calculated.

For the assay a 1 per cent. solution of edestin in 0.1 N hydrochloric acid is placed in test tubes arranged in a constant temperature bath at 37.5° in increments of 0.25 cc., beginning with 0.25 cc. in tube 1. Tubes 4, 5, and 6 receive 1 cc. To the edestin solution is added 0.1 N hydrochloric acid in decrements of 0.25 cc., beginning with 0.75 cc. in tube 1, thus adjusting the volume in each tube to 1 cc. One cc. of 10 per cent. sodium chloride solution is added to each tube to precipitate the protein. This is followed by the addition of 1 cc. of a 1 per cent. solution of the pepsin to be tested in 0.05 N hydrochloric acid. The time from the beginning of the addition of pepsin until the protein is completely liquefied is noted. If the volume of subtrate is represented by s, and the time of digestion by t, then $\frac{t}{s}$ is nearly constant. It is better to adopt the mean $\frac{t}{s}$ for all the tubes as the constant. The comparison of the proteolytic activity of different pepsins resolves itself into a comparison of the constants thus obtained.

[1] Published in *J. Biol Chem.*, 46 (1921) : 119.

NOTES FROM THE U. S. BUREAU OF MINES.*

UNDERGROUND CONDITIONS IN OIL FIELDS.

By A. W. Ambrose.

THE output of oil and gas in the United States is steadily declining. Coincident with this decline is a steadily increasing demand for petroleum and its products, and at present there are no commercial substitutes for lubricating oil. In order to obtain the highest efficiency in the production of oil, the operator should so organize his forces for development and production that he recovers every barrel of oil that can be recovered at a profit. This necessarily involves the use of economical and scientific methods of development and production, and the elimination of waste.

Bulletin 195 of the Bureau, recently issued, outlines methods for the practical application of engineering to underground problems in oil fields.

FLOTATION OF IDAHO ORES.

By Clarence A. Wright.

The United States Bureau of Mines in coöperation with the Idaho Bureau of Mines, the University of Idaho, and certain mining companies is investigating the applicability of differential flotation to the treatment of certain lead and zinc ores of the Coeur d'Alene region and other districts.

The chief metals produced from the ores of the Coeur d'Alene region are lead and zinc, with minor amounts of copper, silver and antimony. Where the minerals are finally disseminated, it is almost impossible to make clean lead and zinc products by the usual methods of gravity concentration, and fine grinding is essential.

Results of flotation tests on samples of mill feeds from a number of mills in this region indicate that the relatively fine slimes produced in the mills can be successfully treated by differential flotation, and this can be effected without any great changes in existing mills. Details of the tests are given in Bulletin 205, recently issued by the Bureau.

* Communicated by the Director.

ANALYSIS OF SULPHUR FORMS IN COAL.

By Alfred R. Powell.

Methods for the analysis of total sulphur in coal have been in use for many years. Technically, a total sulphur determination is useful as indicating one of the factors that fix the value of particular coals for use under steam boilers, for general heating, and for the manufacture of coke and gas.

For certain purposes, however, it is desirable to know not only the total sulphur content, but also how the sulphur is combined in the coal and the exact amount of each form present. Such data are useful in indicating how much of the sulphur can be removed from the coal by washing processes, what effect the sulphur has on the heating value of the coal, how the varying sulphur forms—pyrite, sulphate, organic sulphur—behave during coking and gas making, and other facts of interest to coal technologists.

The writer, while working with S. W. Parr at the University of Illinois, had developed a method for determining sulphur forms that was applicable to Illinois coals. This method has been tested out in the Bureau of Mines laboratories, on coals from other districts, and has been found to be reliable and accurate. Certain modifications were developed to make the method more suitable to routine and rapid commercial analysis. Details of the procedure are given in Technical Paper 254.

GAUZES IN MINERS' FLAME SAFETY LAMPS.

By L. C. Ilsley.

The durability of the gauze used in miners' flame safety lamps, under the various conditions of temperature and other conditions that may affect the lamp, is obviously of the greatest importance. The bureau's specification in testing lamps for their suitability for use in gaseous mines has required steel or charcoal annealed iron wire. As the use of brass and copper gauze has frequently been advocated and in some instances actually used, the Bureau has conducted tests to determine the relative safety of such gauzes as compared with iron and steel. The results have not been deemed of such a nature as to justify changing the present specifications. Details of the tests are given in Technical Paper 228.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, May 18, 1921.)

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, May 18, 1921.

VICE-PRESIDENT MR. COLEMAN SELLERS, JR., *in the Chair.*

By consent, the reading of the minutes of the previous meeting was dispensed with.

The Chairman announced that the first business of the meeting would be the presentation of a Certificate of Honorary Membership to General John J. Pershing, General of the Armies of the United States, and recognized Dr. Harry F. Keller, who read the following resolution passed at the Stated Meeting of the Institute held March 16th last:

> "*Resolved,* That General John J. Pershing, General of the Armies of the United States, be elected to honorary membership in the Institute, in recognition of his signal success in the use of scientific and technical methods and means in modern warfare"

and presented General Pershing to the Chairman.

The Chairman then referred to the General's brilliant services rendered to our country and to mankind and handed him the Certificate of Honorary Membership. General Pershing expressed his thanks for the honor conferred upon him, and spoke appreciatively of the work of American Scientists and Technologists in general and especially of that of the members of The Franklin Institute in the world war.

The Chairman next announced that the annual presentation of The Franklin Medal, the Institute's highest award, in recognition of distinguished scientific and technical achievements would be made, and recognized Dr. Joseph S. Ames, who gave an account of the work of Professor Charles Fabry of the University of Paris, France, recently awarded The Franklin Medal in recognition of

> "His numerous and highly important contributions in the field of physical science, particularly the solution of optical and spectroscopical problems of fundamental importance."

His Excellency M. Jusserand, French Ambassador, was then presented to the Chairman and received from him The Franklin Medal, accompanying Certificate and Certificate of Honorary Membership in the Institute awarded to Professor Fabry. His Excellency conveyed the thanks of his government for the honors conferred upon his distinguished countryman.

Mr. W. C. L. Eglin was then recognized and described the work of Mr. Frank Julian Sprague, of New York City, who had also been awarded The Franklin Medal in recognition of

"His many and fundamentally important inventions and achievements in the field of electrical engineering, notably his contributions to the development of the electric motor and its application to industrial purposes and in the art of electric traction, signally important in forming the basis of world-wide industries and promoting human welfare."

Mr. Sprague was then presented to the Chairman, and received from him The Franklin Medal, accompanying Certificate and Certificate of Honorary Membership in the Institute. Mr. Sprague expressed his thanks for the high honors conferred upon him.

The paper "Studies in the Field of Light Radiation" by Professor Charles Fabry was read by Dr. Joseph S. Ames, Professor of Physics, The Johns Hopkins University.

Mr. Sprague then read his paper "Electric Traction—A Review."

Adjourned.

R. B. OWENS,
Secretary.

(A full account of the meeting will appear in a later issue of the Journal.)

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, May 4, 1921.)

HALL OF THE INSTITUTE,
PHILADELPHIA, May 4, 1921.

MR. CHARLES W. MASLAND *in the Chair.*

The following reports were presented for final action:

No. 2676. Leading-in-Wire for Incandescent Lamps. The Elliott Cresson Medal to Dr. Byron E. Eldred, of New York.

No. 2772. Literature. The Howard N. Potts Medal to Dr. E. V. McCollum, of Baltimore, Maryland.

The following reports were presented for first reading:

No. 2741. Precision Thread Grinder. Dismissed without prejudice.

No. 2769. Variable Pressure Viscometer.

R. B. OWENS,
Secretary.

SECTIONS.

Mining and Metallurgical Section.—A meeting was held in the Hall of the Institute, on Thursday evening, April 7, 1921, at 8 o'clock P.M., with Prof. Alexander E. Outerbridge, Jr., in the Chair. The minutes of the previous meeting were approved as published.

George Otis Smith, Ph.D., Sc.D., LL.D., Director of the U. S. Geological Survey, Department of the Interior, Washington, D. C., delivered an address on "Geology in Partnership with American Industry," in

which the growth of the professions of industrial and engineering geologists was described, as well as their part in the development of American industries.

The communication was discussed by Professor Outerbridge, Doctors Chance and Smith, and others. A vote of thanks was extended to Doctor Smith; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary, pro tem.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 14, 1921, with Mr. George R. Henderson in the Chair.

Mr. N. W. Storer, General Engineer, The Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., presented a paper entitled, "The Characteristics of the Electric Locomotive." The speed and tractive effort characteristics of the different types of electric locomotives were discussed, and a comparison of the similar characteristics of steam locomotives was presented. Questions relating to speed control, regenerative braking and the advantages and limitations of the electric locomotive with respect to short time, heavy loading, mileage etc., were also discussed.

Mr. A. W. Gibbs, Chief Mechanical Engineer, Pennsylvania System, Philadelphia, and a member of the Institute's Board of Managers, presented a communication entitled, "Some Mechanical Characteristics of High-Speed, High-Power Locomotives." In this paper were discussed such questions as the mechanical applications of the electric power and the stability of both steam and electric locomotives as vehicles as determined in road tests on recording track.

Both communications were illustrated with lantern slides.

After a discussion the thanks of the meeting were extended to the speakers.

Adjourned.

R. B. OWENS,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 28, 1921, at 8 o'clock with Dr. George A. Hoadley in the Chair. The minutes of the previous meeting were read and approved.

C. A. Skinner, Ph.D., Chief of the Optical Division, Bureau of Standards, Washington, D. C., presented a communication on "The Polarimeter and Its Practical Applications." The development of polarimetric apparatus was traced, and the uses of such apparatus were described. The lecture was illustrated with experiments and lantern slides.

The paper was discussed; a vote of thanks was extended to Doctor Skinner; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, May 11, 1921.)

NON-RESIDENT.

MR. GEORGE W. MCCLELLAND, 67 First Street, Troy, New York.
MR. ALFRED O. TATE, Cranston, Rhode Island.
MR. FREDERICK K. VREELAND, 90 West Street, New York City.

CHANGES OF ADDRESS.

MR. G. M. BASFORD, 17 East 42nd St., New York City.
DR. EDWIN M. CHANCE, 107 Surrey Ave., Ventnor, New Jersey.
MR. FRANCIS J. COLE, 3 Avon Road, Schenectady, New York.
MR. JAMES A. FLYNN, 3133 Camac Street, Philadelphia, Pennsylvania.
MR. J. K. M. HARRISON, Harrison & Company, Drexel Building, Philadelphia, Pennsylvania.
MR. MALCOLM R. MACLEAN, Haverford, Pennsylvania.
MR. J. V. MEIGS, 33 Clinton Street, Malden, Massachusetts.
MR. CARROLL B. NICHOLS, 1214 Widener Building, Philadelphia, Pennsylvania.
PROF. I. M. RAPP, R. D. 3, Phoenixville, Pennsylvania.
MR. JOHN B. RUMBOUGH, 328 South Center Street, Reno, Nevada.
MR. L. K. SILLCOX, Box 579, Herrick Road, Riverside, Illinois.
PROF. MONROE B. SNYDER, 111 Grand View Road, Ardmore, Pennsylvania.

NECROLOGY.

James S. Whitney, was born in Brownville, Jefferson County, New York, on December 2, 1830, and died in Philadelphia, March 19, 1921.

He came to Philadelphia in 1842, and in 1847 joined his father and brothers in the manufacture of chilled car wheels, a business which was continued for over half a century.

He was actively interested in civic and municipal affairs, and was for many years a member of the Board of Education of Philadelphia. He was a Life Member of the Institute.

Mr. Henry Spencer Blackmore, 1 West 34th Street, New York City.
Mr. Joseph C. Fraley, 1815 Land Title Building, Philadelphia, Pennsylvania.
Mr. Joseph B. Rohrman, Drexel Hill, Pennsylvania.
Mr. Lewis Seal, 217 Cooper Street, Camden, New Jersey.
Mr. William Smith, 1417 W. Dauphin Street, Philadelphia, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

BROMLEY, H. A.—Paper and Its Constituents. 1920.
CARMAN, E. S.—Foundry Moulding Machines and Pattern Equipment. 1920.
CARR, H. W.—General Principles of Relativity. 1920.

COLVIN, F. H. and ETHAN VIALL.—United States Rifles and Machine Guns. 1917.
FALK, G. K.—The Chemistry of Enzyme Actions. 1920.
FISCHER, EMIL.—Introduction to the Preparation of Organic Compounds. 1917.
HALE, S. A.—The Coal Trade. 1920.
HUNZIKER, OTTO F.—Condensed Milk and Milk Powder. 1920.
JACKSON, DOUGLAS H.—Detail Design of Marine Screw Propellers. 1920.
JACKSON, D. C. and C. P.—Alternating Currents and Alternating Current Machinery. 1920.
PEELE, ROBERT.—Compressed Air Plant. 1920.
SEARLE, A. B.—Modern Brickmaking. 1920.
SOTHERN, J. W. M.—Oil Fuel Burning in Marine Practice. No date.
SUTERMEISTER, E.—Chemistry of Pulp and Paper Making. 1920.
THOMSEN, T. C.—The Practice of Lubrication. 1920.
WILLIAMS, K. P.—Dynamics of the Airplane. 1921.

GIFTS.

The Family Adviser; or a plain and modern practice of physic; calculated for the use of famlies who have not the advantages of a physician. . . . by Henry Wilkins, M.D. The fifth edition, to which is annexed Mr. Wesley's Primitive Physic, revised, 286 pages, 16mo., New York, Daniel Hitt and Thomas Ware, 1814. (From Mr. D. N. Ogden.)

Valuable Secrets Concerning Arts and Trades; or, approved directions, from the best artists for the various methods of engraving on brass, copper, or steel, of the composition of metals and varnishes. etc. . . . 240 pages, 12mo., Norwich, Thomas Hubbard, 1795. (From Mr. D. N. Ogden.)

Franklin, Benjamin, Life, Written by Himself. New York City, New York, 1824.

A Collection of the Familiar Letters and Miscellaneous Papers, now for the first time published. Boston, Massachusetts, 1833. (From Mr. J. A. P. Crisfield.)

Aldrich Pump Company, "Hydraulic Machinery." Allentown, Pennsylvania, 1920. (From the Company.)

American Arch Company, The Locomotive Heat Balance. New York City, New York, 1921. (From the Company.)

American District Steam Company, Bulletin No. 151, 152 and 153. New York City, New York, 1921. (From the Company.)

American International Corporation, Report of the President for 1921. New York City, New York, 1921. (From the Corporation.)

American Sugar Refining Company, Annual Report for 1920, New York City, New York, 1920. (From the Company.)

Amherst College, Catalogue of the College for 1920–1921. Amherst, Massachusetts, 1921. (From the College.)

Armstrong Brothers Tool Company, Catalogue B-20. Chicago, Illinois, 1920. (From the Company.)

Baker, J. T., Chemical Company, Catalogue of Baker's Analyzed Chemicals with Typical Analysis. Phillipsburg, New Jersey, 1920. (From the Company.)

Barber-Greene Company, Cost Data of Barber-Greene Methods. Aurora, Illinois, 1920. (From the Company.)

Brady, The James A., Foundry Company, "Twelve Fuel Facts About the Harrington Stoker." Chicago, Illinois, 1920. (From the Company.

Bristol Company, Catalogue No. 712. Waterbury, Connecticut, 1921. (From the Company.)

Burden Iron Company. Catalogue. Troy, New York, 1920. (From the Company.)

Canada Department of Mines, Annual Report for the Year 1919. Ottawa, Canada, 1920. (From the Department.)

Case, J. I., Threshing Machine Company, Case Kerosene Tractors and Grand Detour Plows and Case Power Farming Machinery. Racine, Wisconsin, 1920. (From the Company.)

Chase, Frank D., Incorporated, "Factories that Fit." Chicago, Illinois, 1921. (From the Corporation.)

Chicago Mill and Lumber Company, Booklet "Boxes." Chicago, Illinois, 1920. (From the Company.)

College of Physicians, Transactions, Vol. xli. Philadelphia, Penna., 1919. (From the Secretary.)

Columbian Bronze Corporation, "Propellers in a Nut Shell." New York City, New York, 1920. (From the Corporation.)

Connecticut State Board of Health and Bureau of Vital Statistics, Sixty-eighth and Sixty-ninth Registration Report for 1915-1916. Hartford, Connecticut, 1919. (From the Board.)

Cory, Chas., and Son, Incorporated, Bulletins Nos. 29A, 33-39A. New York City, New York, 1920. (From the Corporation.)

Cutler-Hammer Manufacturing Company, "For the Mine." Milwaukee, Wisconsin, 1920. (From the Company.)

Dartmouth College, The Catalogue 1920-1921. Hanover, New Hampshire, 1920. (From the College.)

Denison University, Annual Catalogue 1920-1921. Granville, Ohio, 1921. (From the University.)

Denver Fire Clay Company, Bulletin No. 251. Denver, Colorado, 1920. (From the Company.)

Edwards, O. M. Company, Incorporated, Catalogue No. W-19. Syracuse, New York, 1920. (From the Company.)

Electric Hoist Manufacturers' Association, "The Strong Arm of Industry." New York City, New York, 1920. (From the Association.)

Hagan Corporation, "Boiler Regulation." Pittsburgh, Pennsylvania, 1920. (From the Corporation.)

Harvard College Observatory, Annals, Vols. 81, pt. 5; 83, pt. 5; 95. Cambridge, Massachusetts, 1921. (From the Director.)

Institution of Civil Engineers, Minutes of Proceedings. Vol. ccvii. London, 1920. (From the Institution.)

Institution of Engineers and Shipbuilders of Scotland, Transactions Vols. lxii and lxiii, 1918-1920. Glasgow. (From the Institution.)

International Nickel Company, Monel Metal. New York City, New York, 1920. (From the Company.)

Kelly, William E., Electricity the Burden Bearer. Chicago, Illinois, 1920. (From the Author.)

Library of Congress, A List of Geographical Atlases, Vol. iv. Washington, D. C., 1920. (From the Library.)

Mason Regulator Company, The Mason Book. Boston, Massachusetts, 1920. (From the Company.)

Massachusetts State Department of Health, Fifth Annual Report. Boston, Massachusetts, 1920. (From the Department.)

McCrosky Tool Corporation, Catalogue No. 8. Meadville, Pennsylvania, 1921. (From the Corporation.)

Mica Insulator Company, Catalogue No. 85. New York City, New York, 1921. (From the Company.)

New South Wales Water Conservation and Irrigation Commission, Report for the Year ended June 30, 1920. Sydney, Australia, 1920. (From the Director.)

Niles-Bement-Pond-Company, "Maag Gears." New York City, New York, 1920. (From the Company.)

Northern Engineering Works, Catalogue No. 28. Detroit, Michigan, 1920 (From the Works.)

Ohio Brass Company, Catalogue No. 18. Mansfield, Ohio, 1921. (From the Company.)

Parke, Davis and Company, Collected Papers from the Research Laboratory, Detroit, Michigan, 1920. (From the Director.)

Pennsylvania Electric Association, Proceedings of the Eighth, Ninth, Tenth, and Eleventh Annual Conventions, 1915–1918. Harrisburg, Pennsylvania. (From Mr. H. M. Stine, Secretary.)

Revolvator Company, Booklet, The Revolvator. Jersey City, New Jersey, 1920. (From the Company.)

Roberts and Schaefer Company, Bulletin Nos. 39–40. Chicago, Illinois, 1920. (From the Company.)

Slosson Edwin E., Creative Chemistry. New York City, New York, 1920. (From the Chemical Foundation.)

Society of Engineers, Transactions for 1920. London, England, 1920. (From the Society.)

South Australia Director of Mines and Government Geologist, Annual Report for 1919. Adelaide, South Australia, 1920. (From the Director.)

Standard Scientific Company, Suggestions for Laboratory Exercises in Optics. New York City, New York, 1921. (From the Company.)

Stanford University, Report Upon a Collection of Coccidæ from Lower California, Stanford University, California, 1921. (From the University.)

Stevens Institute of Technology, Annual Catalogue for 1921–22. Hoboken, New Jersey 1921. (From the Institute.)

Sturtevant, B. F. Company, Catalogue No. 276. Boston, Massachusetts, 1920. (From the Company.)

Sweet's Catalogue Service, Incorporated, Sweet's Engineering Catalogue, Seventh Annual Edition. New York City, New York, 1921. (From the Corporation.)

United States Naval Observatory, American Ephemeris for 1923 and Publication Vol. ix, Part 1. Washington, D. C., 1921. (From the Observatory.)

University of Pennsylvania, Catalogue 1920–1921. Philadelphia, Pennsylvania, 1921. (From the University.)

University State of New York, 14th Annual Report, Vol. iii. Albany, New York, 1920. (From the University.)

University of Virginia, Catalogue 1920-21. Charlottesville, Virginia, 1921. (From the University.)

Vanderbilt University, Register 1920–1921. Nashville, Tennessee, 1921. (From the University.)

Vogt, Henry, Machine Company, Bulletin No. 5, Louisville, Kentucky, 1920. (From the Company.)

Vulcan Crucible Steel Company, "Vulcan Tool Steels" Catalogue. Aliquippa, Pennsylvania, 1921. (From the Company.)

Western Australian Institution of Engineers, Proceedings, Vol. vii, viii, ix, and x. Perth, Western Australia, 1920. (From the Institution.)

Western Machine Tool Works, Catalogue No. 21. Holland, Michigan, 1921. (From the Works.)

Western Reserve University, Catalogue 1920–1921. Cleveland Ohio, 1921. (From the University.)

Wing, J. L., Manufacturing Company, "Wing Turbine Blower." New York City, New York, 1920. (From the Company.)

BOOK NOTICES.

INTERNATIONAL ASSOCIATION OF CHEMICAL ENGINEERS. Proceedings of the third session of the Council held at Solvay Institute, Leopold Park, Brussels, 1913.

Though relating to actions taken before the great war, and representing international amities that have been broken by recent events, this pamphlet has considerable interest, as an attempt to establish greater uniformity in chemical and physical notation and nomenclature. A conference of certain portions of the old organization was held in Rome in June, 1920, at which further efforts were made towards uniformity. The principal point in the present circulation of the pamphlet is to invite action on the unification of the symbols in physical chemistry, a list of which, with comments, is given. In the session of 1913, steps were taken towards unification of the abbreviations of the names of Journals devoted to chemistry and allied branches, and, among other matters, William Ostwald urged the adoption of Ido (a modified Esperanto) as an international language, but his suggestion does not appear to have been taken up. Even in the brief summaries of the discussions, it is painfully evident that a systematic unification of the several systems of nomenclature and notation in the physical and chemical sciences will be a very difficult task, and the outlook for even moderate reform is not encouraging.

HENRY LEFFMANN.

LEHRBUCH DER FARBENCHEMIE, EINSCHLIESSLICH DER GEWINNUNG UND VERARBEITUNG DES TEERS, SOWIE DER METHODEN ZUR DARSTELLUNG DER VOR- UND ZWISCHENPRODUKTE. By Dr. Hans Th. Bucherer, Ordinary Professor (retired) in the Dresden Technical High School, and instructor in the Berlin Technical High School. Second revised edition xi—580 pages, contents, index and bibliography. Leipzig, Otto Spamer. $8.40, in paper; $9.10, bound.

In this excellently printed volume we have a most comprehensive presentation of the intricate and extensive chemistry of those derivatives of tar that are of importance in the manufacture of the colors. So great is the amount of data presented that the reviewer scarcely knows where to begin. Some idea of the material may be gained by a summary of the table of contents. The work is divided into three main sections or chapters. The first, comprising sixty-seven pages, describes the tar from bituminous coal, its production and its preliminary treatment. The second section describes the intermediates, and comprises one hundred and eighty-nine pages. The third section, comprising three hundred and twenty-five pages, is the specific description of the artificial colors and a sub-section of fifty-nine pages on the natural colors. The latter are of very ancient and wide-spread use; mostly derived from vegetable sources, but one famous color, the Tyrian purple, especially characteristic of royalty was obtained from a species of shell fish. It is stated in this book that this color has been found to be analogous to indigo. In connection with the description of the "vat-dyes," of which indigo is the most important representative, and which have figured so largely in the recent discussions on tariff legislation regarding coal-tar products, it is worth while to summarize some statistics concerning indigo production. The struggle for production of synthetic colors, identical or equivalent to the natural forms, began early in the development of the coal tar industry. The first brilliant success was with alizarin. This, originally, entirely derived from the madder plant, was synthetized in 1868 by Graebe and Liebermann, and the process much improved by Caro in the succeeding year. Before long the artificial product had completely displayed the natural one. The great importance of indigo, and the knowledge that its principal coloring matter is analogous to tar products (in fact, anilin derives its name from the specific name of one of the indigo yielding plants, having been obtained among the products of the destructive distillation of that color) suggested research. It was in 1895, that the *Badische Anilin und Soda Fabrik* began the manufacture of the color in competition with the natural product. It was about this time that the late Raphael Meldola, in London, warned the English indigo-growers, who were the principal producers, that German competition was likely to interfere with their market, but they gave no special heed to his words. The early German enterprise was not very successful, but the procedures were constantly improved, until at the opening of the great war, the bulk of indigo used was "made in Germany." The statistics are informing. In 1895 the importation of indigo into Germany was valued at Mk. 21,500,000; by 1913, the importations had fallen to a mere trifle. The exports of the color from Germany were negligible in the latter years of the 19th century, but by 1913 had acquired

a volume valued at Mk. 55,000,000. The production in India fell off steadily until the outbreak of the war, which, of course, cut off the German supply, and redeveloped the orginal industry, but towards the ending of the war a relaxation of the activity of the India fields set in. This is ascribed to the great increase of the difficulties of sea-borne traffic, in consequence of the activity of submarines. The author adds the comment, "The outlook for natural product in competition with the synthetic is not very rosy; notwithstanding the labors of English chemists, here, as in other cases, the German inventive genius and intrepid spirit will determine the victory." In Germany the price of the color fell from about Mk. 16 in 1895, to less than Mk. 6 in 1904. Much of this decrease was due to the competition between the two great producers, the BASF and the Hoechst works. This condition was eliminated by an agreement between the two firms, and the price was held at Mk. 7.50. The reduction accomplished, as compared with the earlier years, gave rise to a much increased use of the color. Unexpectedly in very recent time, it has been found that a treatment of indigo blue with benzoyl chloride in presence of copper-dust effects a change to a new color—indigo yellow—the composition of which is yet not clearly ascertained. This permits of the production of a fine green on both wool and cotton, when associated with indigo.

It is evident from the above selections that the work is a very comprehensive and detailed statement of all the important chemistry of the coal-tar colors. All the colors are explained as to their production, their composition being shown by structural formulas, of which there are many hundreds in the work.

The American reader will be a good deal interested in the evidence afforded by the book as to Germany's ability to recover the old control of this industry. A quotation given above shows the feeling in regard to the English indigo industry, but that is a competition between a natural and an artificial product. What is the outlook for the establishment of independent synthetic color industries in the other great nations? The question is a live one, not only on account of the color-manufacture proper, but because it is now recognized that the principal munitions of war—high explosives and poisonous gases—are largely produced by comparatively simple modifications of the methods employed in color manufacture. This turn-over in a short time from one form of procedure to the other cannot be accomplished unless the given nation has already developed large and efficient plants for carrying out all the operations with tar. Even these will not be of use, unless there is high technical skill and originality in the application of existing knowledge to the problems as they arise.

The reviewer not unnaturally institutes a comparison between the book in hand and that of Dr. Lange, reviewed a few months ago. Both relate to the tar industries, but the older book was limited to the intermediates. It was particularly commendable for the vividness with which each item was presented so much so that one of the items was reproduced as it is in the book. The book now under consideration does not follow Lange's method, but uses side-notes very liberally, which serve a

good purpose and guide the user of the work to the place desired. It is a question why Dr. Bucherer has deemed it necessary to give with many of the ring formulas the supposititious double bonding. Kekulé, in his original paper, gave the plain hexagon as standing for benzene, and while the particular distribution of the double bonding has been a matter of much discussion in theoretical chemistry, there seems to be no reason for considering that phase in such a work as this. It is to be regretted that the German chemists still adhere to the unscientific terms "benzol," "toluol" and similar titles, when the world at large has adopted the "ene" termination, and limited "ol" to alcoholic structure. There is an extensive classified bibliography, but it seems that it would have been better to give the references at the point of which the information is stated, giving the whole list of references in their numerical order at the close. There is an excellent index.

The first fifty pages are taken up with historical and statistical matter. The early history of the coal-tar industry is not very creditable to England and France, for although the first steps in the utilization of the tar were made in the former country, the leading men of both failed to appreciate the possibilities of the industry, and even cheapened the value of the work being done in Germany. On page 7, Dr. Bucherer speaks briefly, in a foot-note of the probable duration of the world's coal supply. Such a speculation might be left unnoticed, as cases of this nature are of little or no value. The introduction of new sources of power may limit the use of coal, and many coal-fields may be found at present unsuspected. The statements in the foot-note, however, deserve a little more careful attention, for the author states that the coal-supply of Germany will last three thousand years, that of England only seven hundred years, and the North American supply only one thousand seven hundred years. The Coal deposits will, therefore, he says, be exhausted sooner in England and in the United States than in Germany. There seems to be a sinister meaning in this sentence, and the reply may appropriately be that even if true, seven centuries is a good while to wait for "Der Tag."

HENRY LEFFMANN.

ON THE DIFFUSION OF LIGHT BY THE MOLECULES OF TRANSPARENT GASES. Jean Cabannes. A Thesis Presented to the Faculty of Sciences, University of Paris, June, 1920. 149 pages, 8vo.

On one occasion when Lord Kelvin was presiding at a session of the Physics Section of the British Association for the Advancement of Science an auditor noted how he reconciled truthfulness with tact in his remarks at the close of the papers presented. When a genuinely valuable paper had been read the great physicist said in effect something about "this important contribution to an interesting subject," but, on the other hand, after a paper of mediocre value he would speak of "this interesting contribution to an important subject." To the thesis of M. Cabannes both adjectives "interesting" and "important" are fitting. The work is valuable because it materially increases our knowledge of the diffusion

of light from the sky and throughout it is distinguished by the lucidity of presentation and symmetry of arrangement so characteristic of the Gallic scientists.

In the historical introduction the author sketches the attempts made in the second half of the nineteenth century to explain the blue of the sky from the supposititious water bubbles of Clausius onward through suggestions of fluoresence and selective absorption to a fixing of belief about 1900 upon diffusion by small particles as the real cause. In 1899 Lord Rayleigh advanced the proposition that the small particles concerned are none other than the molecules of the air. This is, of course, in direct contradiction to Tyndall's experiment showing, as he thought, air without floating particles to be "optically empty." This hypothesis soon found confirmation in the observations of Abbot and Fowle on Mt. Wilson, 1910–1911, from which it was deduced that the number of diffusing centres equaled the number of gaseous molecules. Any observations made on light from the sky are complicated by the fact that each point diffuses not alone the light from the sun, but also that coming from other points of the sky and from the earth as well. In 1913, M. Cabannes turned to the study of the phenomena in the laboratory and early in 1915 made known the first experimental proof that gas molecules really do diffuse light. Since that time others have reached the same conclusion.

In Part I a discussion of the theory of the diffusion of light by particles whose diameters are small in comparison with the wave-length is presented. According to the theory elaborated by Lord Rayleigh in 1871, the intensity of the diffused light is inversely proportional to the fourth power of the wave-length. Thus when the sunlight passes through the air the waves of shortest length are those chiefly diffused—in other words, the blue light is diffused laterally while the red and yellow, suffering less diffusion, pass through with less change in intensity. The English peer assumed that the air molecules are spherical, and from this it followed that the light diffused at right angles to the incident beam should be completely plane polarized. Experiment, however, shows that this is not the case. For this reason the author develops the theory for gas molecules not spherical but ellipsoidal in shape, no two axes being of the same length. From his experimental results for air interpreted by his theory comes a value for the number of molecules in a cubic centimeter of gas under standard conditions equal to 2.92×10^{-19} (Millikan obtained 2.709; Rutherford, 2.78; Perrin, 3.06) and for Avogadro's Constant, 65.4×10^{22} (Millikan, 60.7; Rutherford, 62.3; Perrin, 68.5).

Part II is devoted to a discussion of the observations of Abbot and Fowle, which confirm the prediction of Rayleigh that outside of bonds of selective absorption, the intensity of diffused light is as the reciprocal of the fourth power of the wave-length. Minimal values for the constants just mentioned are derived, viz. 2.92×10^{19} and 6.45×10^{23}, respectively.

In Part III, occupying by far the largest portion of the entire 149 pages, the experimental work of the author is described. A beam of light was sent through a mass of gas filtered to free it from foreign particles. The light coming at right angles from the path of the beam in the gas fell on a

photographic plate, where the density of the image could be studied at leisure. From the lengthy series of experiments, carefully devised and protected from error, a number of important conclusions are drawn.

1. A transparent gas illuminated by a beam of light emits in turn light in all directions. Argon, hydrogen, oxygen, nitrogen and carbon dioxide were used, as well as air. The light from hydrogen was very faint, as is seen from the reproduction of the photographic imprint, while that from carbon dioxide was two or three times as strong as the light from air and ten times as strong as that emitted by hydrogen.

2. The radiation emitted laterally by the illuminated gas is composed of the same radiations as the primary beam. Of course the relative intensities of various wave-lengths are different as a result of the inverse fourth-power law. No trace of fluorescence was detected.

3. In the light diffused by a gas the intensity of any wave-length depends solely upon the intensity of that wave-length in the incident radiation and not on the spectral composition of the incident light.

4. The plane polarization of light at right angles to the incident ray is not complete in general and the Fresnel vibration is perpendicular to the plane containing the incident and diffused ray. The gas molecules appear in consequence to be not spherical.

5. When the incident ray passes through a vacuum all trace of the laterally diffused light vanishes.

6. The quantity of energy diffused by a gas under a certain pressure is a constant characteristic of the gas.

7. The quantity of energy laterally diffused by a gas is proportional to the pressure of the gas.

8. The light emitted laterally by argon is totally polarized. It is therefore admissible to assume that the argon molecule is spherical. Then applying Rayleigh's theory the value of Avogadro's Constant comes out 6.9×10^{23}.

The author is to be congratulated on the completion of this laborious research so long interrupted by the war.

GEORGE F. STRADLING.

RECOVERY OF NITRATE FROM CHILIAN CALICHE, CONTAINING A VOCABULARY OF TERMS, AN ACCOUNT OF THE SHANKS SYSTEM, WITH A CRITICISM OF ITS FUNDAMENTAL FEATURES AND A DESCRIPTION OF A NEW PROCESS. By A. W. Allen, M.A., Chemical and Metallurgical Engineer. xvi–48 pages, index and diagrams, 12mo. London, Charles Griffin & Company, Ltd.; Philadelphia, J. B. Lippincott Company, 1921.

Caliche is the crude sodium nitrate found in the Chilian deposits, quite variable in composition. The book in hand is a discussion of the processes adapted to the refining of the raw material, and the subject matter, therefore, has little interest for those not engaged in this special work. The extraction of sodium nitrate from this deposit began in the early part of the nineteenth century, the area then being under the control of Peru. At this early period, the caliche contained on an average about 75 per cent. of sodium nitrate, but the richness has been steadily diminishing, and the cruder procedures of the older time

are not profitably applicable. The author presents the difficulties of the method generally in use, and offers an improved process of his own invention. The book is a valuable contribution to a process of mining which is practically unique and which has had a profound influence on the world's history in the last hundred years. As has happened with many other deposits of valuable mineral, much material has been thrown on the dump because extraction did not pay, but according to Mr. Allen, many millions of tons of caliche or residues rejected for such reasons are available if improved methods are applied. A valuable feature of the book is the vocabulary of terms relating to the subject. The question of the future of the nitrate beds is especially important in view of the progress that has been made in nitrogen fixation which may ultimately render the greater nations independent of these deposits.

HENRY LEFFMANN.

BIBLIOTHECA CHEMICO-MATHEMATICA. A catalogue of works in many tongues, on Exact and Applied Science. With a subject index. Compiled and annotated by H. Z. and H. C. S. In two volumes, having a total of 964 pages, with 127 plates, having 247 portraits and fac-similes, 8vo. London, Henry Sotheran & Co., 1921. £3.3 shillings net.

Although having the general appearance of an extra illustrated book catalogue, these two attractive volumes are really a bibliography of literature, past and present, relating to the physical sciences. The very numerous well-executed fac-similes give the reader an idea of the character of the books of the centuries immediately following the introduction of the art of printing. The identity of H. Z. is told in the preface. He is Heinrich Zeitlinger, of Linz, who is described as an "equal well-wisher of learning and of England" (Linz is in Austria, on the Danube). The identity of H. C. S. is not specifically disclosed but it does not need Sherlock Holmes to tell us that it is the present head of the house, Henry Cecil Sotheran. Why the initials should be used instead of the full names is a puzzle. Perhaps it is intended to be in keeping with earlier customs, as when a play was entered at Stationers' Hall as published by T. C. for W. S.

While not a complete bibliography of the literature, inasmuch as it represents only those works that the firm has for sale, the number of books noticed is very large and from them could be selected a good library of the early publications in the sciences included in the scope of the book. Almost all of the entries are accompanied by notes and comments, often quite interesting. The prices quoted do not seem high in comparison with those that usually obtain in the sale of private collections, but presumably "first editions" of scientists and mathematicians are not as much sought for as in other classes of literature. The illustrations are all well made and add greatly to the value and interest of the book. A mistake in one of the notes should be pointed out. It is stated that Ampère's name "is immortalized in electrical science as the unit of electromotive force." The ampère is the unit of current; that of electromotive force is the volt.

The classification in the main body of the work is alphabetically by authors, but the publisher has placed scientists under much obligation by

an elaborate classification index by subjects, so that one interested in a particular line of science can find with but little trouble the works relating to it. The list is not confined to early books; comparatively modern editions and well-known contemporary publications are listed to a limited extent, but the real attractiveness of the catalogue is the books of the earlier period, and the many fac-similes of their pages. A number of very excellent portraits are included. That of Thomas Young is especially worthy of mention as a specimen of photogravure and printing.

The mechanical execution of the book is first class: good paper, good printing and good binding.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 93, Properties of Aerofoil Sections, 83 pages, diagrams, quarto. Washington, Government Printing Office, 1921. The object of this report is to bring together the investigations of the various aerodynamic laboratories of this country and Europe upon the subject of aerofoils suitable for use as lifting or control surfaces on aircraft. The data have been so arranged as to be of most use to designing engineers and for purposes of general reference.

The absolute system of coefficients has been used, since it is thought by the Committee that this system is the one most suited for international use, and yet is one for which a desired transformation can be easily made. For this purpose a set of transformation constants is included in this report.

Each aerofoil section is given a reference number, and the test data are presented in the form of curves from which the coefficients can be read with sufficient accuracy for design purposes. The dimensions of the profile of each section are given at various stations along the chord in per cent. of the chord using as datum the line shown on the curves. The shape of the section is also shown with reasonable accuracy to enable one to more clearly visualize the section under consideration together with its characteristics. The more accurately to obtain the dimensions of the profile of each section, a separate data sheet for each section has been included, which gives an additional decimal place for the greater portion of the ordinates.

Report No. 100, Accelerometer Design, by F. H. Norton and Edward P. Warner. 16 pages, illustrations, quarto. Washington, Government Printing Office, 1921.

In connection with the development of an accelerometer for measuring the loads on airplanes in free flight a study of the theory of such instruments has been made, and the results of this study are summarized in this report. A portion of the analysis deals particularly with the sources of error and with the limitations placed on the location of the instrument in the airplane. The discussion of the dynamics of the accelerometer includes a study of its theoretical motions and of the way in which they are affected by the natural period of vibration and by the damping, together with a report of some experiments on the effects of forced vibrations on the record.

Report No. 102, performance of a Liberty 12 Airplane Engine, by S. W.

Sparrow and H. S. White. 20 pages, illustrations, quarto. Washington, Government Printing Office, 1921.

In coöperation with the Engineering Division of the Air Service of the United States Army, a Liberty 12 engine has been tested at the Bureau of Standards. The program of tests was planned to yield that information considered most important in determining the value of the engine for aviation. Full power runs were made at the ground at 25,000 feet, and at several intermediate altitudes. To determine the mechanical efficiency of the engine friction horse-power was measured at the ground and at 15,000 feet. As a basis for predicting engine performance with a propeller, a series of tests were made in which the dynamometer load and engine throttle were adjusted at each speed to simulate the engine load which would be imposed at that speed by a propeller operating under normal full load at 1,700 r.p.m.

Among the quantities calculated from the test measurements are: Brake horsepower; brake mean effective pressure; fuel consumption; mixture ratio; mechanical, thermal, and volumetric efficiency; and the percentage of heat in the fuel appearing in the jacket water and in the exhaust. Jacket water temperature, oil temperature, manifold pressure, etc., are recorded to show the conditions under which the test was made.

The provision on the carburetor for adjusting the mixture ratio is shown to be inadequate at altitudes above 15,000 feet. Improving the mechanical efficiency of the engine and making such changes as will prevent the present decrease of volumetric efficiency with increase of altitude are suggested as two possibilities of improving the altitude performance of the engine.

PUBLICATIONS RECEIVED.

Eléments de Géométrie par Alexis—Claude Clairant. 2 vols., illustrations, 16mo. Paris, Gauthier-Villars et Cie, 1920, price 3 francs 50 each.

Reflexions sur la Métaphysique du Calcul Infinitesimal par Lazare Carnot. 2 vols., illustrations, 16mo. Paris, Gauthier-Villars et Cie, 1921, price 3 francs 50 each.

Coke-oven and By-product Works Chemistry, by Thos. Biddulph Smith, F.C.S. 180 pages, illustrations, plates, diagrams, 8vo. London, Charles Griffin & Company, Limited; Philadelphia, J. B. Lippincott Company, 1921.

The recovery of Nitrate from Chilian Caliche, containing a vocabulary of terms, an account of the Shanks system, with a criticism of its fundamental features, and a description of a new process. By A. W. Allen, M.A., (Camb.), 50 pages, illustrations, 12mo. London, Charles Griffin & Company, Limited; Philadelphia, J. B. Lippincott Company, 1921.

Cours de Mécanique Appliquée a l'usage des élèves al'Institut electrotechnique Tome II Statique graphique et résistance des matérianx, par Louis Roy. 216 pages, illustrations, 8vo. Paris, Gauthier-Villars, 1921, price 30 francs.

Laboratory Aids in Practical Mechanics for Elementary Students, by G. S. Bowling. 100 pages, illustrations, 16mo. London, Charles Griffin & Company, Limited; Philadelphia, J. B. Lippincott Company, 1921.

The Pennsylvania Survey, Miscellaneous Papers, No. 1. The Story of the Pennsylvania Survey, by George H. Ashley, State Geologist. 20 pages, illustrations, quarto. Harrisburg, Bureau of Topographic and Geologic Survey, 1921.

U. S. War Department. Annual Reports, 1920. 3 volumes, illustrations, plates, 8vo. Washington, Government Printing Office, 1921.

University of Toronto Engineering Society. Transactions and Year Book. No. 34, 1920-1921. 176 pages, illustrations, portraits, 8vo. Toronto, Society, 1921.

U. S. Bureau of Mines. Monthly statement of coal mine fatalities in the United States, February, 1921, by W. W. Adams, 8 pages, 8vo. Technical paper 228, The relative safety of brass, copper and steel gauzes in miners' flame safety-lamps, by L. C. Ilsley and A. B. Hooker. 39 pages, illustrations, plates, 8vo. Technical paper 246, Water-gas apparatus and the use of central district coal as generator fuel, by William W. Odell, 28 pages, 8vo. Technical paper 286, Metal-mine accidents in the United States during the calendar year 1919 (with supplemental labor and accident tables for the years 1911 to 1919, inclusive), by William W. Adams, 99 pages, 8vo. Washington, Government Printing Office, 1921.

Ten Years' Progress in Water Works Pumps, with notes on duty and economy comparisons, testing of steam turbines and centrifugal pumps, measuring head and flow, flow of water in pipes, etc. A manual for water works officials and engineers. 100 pages, illustrations, diagrams, quarto. Trenton, N. J., De Laval Steam Turbine Co., 1921.

National Advisory Committee for Aeronautics. Technical Notes, No. 41. Influence of span and load per square meter on the air forces of the supporting surface, by A. Betz. Translated from *Technische Berichte* by Lieut. Walter S. Diehl. 7 pages, illustrations, quarto. No. 45. Extract from a report on the resistance of spheres of small diameter in an airstream of high velocity, by Capt. Toussaint and Lieut. Hayer, Aerotechnical Institute of Saint Cyr. 9 pages, illustrations, quarto, No. 50, The Gordon Bennett Airplane Cup, 1920, by W. Margoulis. 13 pages, illustrations, quarto. Washington Committee, 1921.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

INDEX TO VOL. 191.

Acoustics, meteorological (Humphreys), 581

Aeronautic instruments (Mendenhall), 57

Airplane stability. Harmonic oscillations (Zahm), 381

Airplane wings, Ground-plane influence on (Zahm and Bear), 687

America's petroleum problem (Lewis), 357

AMES, JOSEPH S.: Einstein's principle of relativity and its bearing upon physics, 1

Anisotropic liquids (van der Lingen), 651

ARMSTRONG, A. H.: The economic aspects of railway electrification, 493

Atmospheric disturbances, or static in radio telegraphy (Austin), 619

AUSTIN, L. W.: Atmospheric disturbances, or static in radio telegraphy, 619

BEAR, R. M., and A. F. ZAHM: Ground-plane influence on airplane wings, 687

BOGERT, MARSTON TAYLOR: The bearing of a synthetic dye industry upon our national welfare, 445

BOOK NOTICES:

Allen, A. W.: Recovery of nitrate, 859

Amar, Jules: The human motor, 295

Autenrieth, W.: Laboratory manual for the detection of poisons, ed. 5, 562

Battle, J. R.: Hand-book of industrial oil engineering, 140

Bibliotheca Chemica-Mathematica, 860

Born, M.: Die Relativitätstheorie, Einstein's, 558

Bucherer, H. T.: Lehrbuch der Farbenchemie, 855

Cabannes, J.: On the diffusion of light, 857

Clarkson, R. P.: Elementary electrical engineering, 564

Collis, E. L.: The health of the Industrial worker, 720

Cook, E. P.: Laboratory experiments in organic chemistry, 140

Coupaux, H.: Introduction to general chemistry, 429

Cushman, A. S.: Chemistry and civilization, 141

Gardner, Henry A.: Papers on paint and varnish, 297

Gordon, A.: French-English medical dictionary, 431

Hood, G. F. and J. A. Carpenter: A text-book of practical chemistry, 561

International Association of Chemical Societies, Proceedings, 854

Journal of Indian Industries and Labor, 720.

Lange, Otto.: Die Zwischenprodukte der Teerfarbenfabrikation, 138

McGuigan, H.: An introduction to chemical pharmacology, 563

Molinari, E.: Treatise on general and industrial organic chemistry, 432

National Advisory Committee for Aeronautics, Reports 143, 299, 434, 564, 722, 861

Penroses Annual, The process yearbook, vol. xxiii, 430

Schneider, A.: The micro-analysis of powdered drugs, ed. 2, 431

Smith, Edgar F.: Priestley in America, 296

Spiers, F. S.: The microscope, 560

Threlfall, H.: A text-book of surveying and levelling, 562

Ulbricht, R.: Das Kugelphotometer, 294

Youngken, H. W.: Pharmaceutical botany, ed. 3, 433

Zsigmondy, R.: Kolloidchemie ed. 3, 559

BULLARD, W. H. G.: The application or radio to navigation problems, 725

Cargo vessel, The modern (Gatewood), 331

CORLEY, WILLIAM A.: Initiation of military explosives, 87

Crystals, structure of, the determination of the (Wyckoff), 199
CULVER, CHARLES A.: Guided-wave telephony, 301
CURRENT TOPICS: 21, 22, 56, 86, 120, 124, 128, 132, 144, 197, 198, 230, 257, 258, 263, 264, 278, 281, 282, 287, 288, 329, 330, 379, 380, 404, 418, 436, 437, 492, 523, 524, 542, 548, 566, 567, 618, 630, 678, 686, 694, 708, 712, 766, 818, 821, 822, 831, 839, 842, 864

da Vinci, Leonardo, philosopher and engineer (Lieb), 767
Deformation, A new general law of (Nutting, P. G.), 679
Delaware Bay, Tidal observations off the entrance to (Marmer), 819
Developing-out papers, A sensitometric study of the reduction of (Jones and Fawkes), 503
Disposal of industrial wastes (Emerson), 807
DUNCAN, R. D., JR.: Recent attainments in wired radio, 23
Dye industry, The bearing of a synthetic, upon our national welfare (Bogert), 445

Eastman Kodak Company: Research Laboratory Notes, 279, 417, 841
Einstein's principle of relativity (Ames), 1
Electron tubes, Some operating characteristics of (White), 473
EMERSON, C. A.: Disposal of industrial wastes and stream pollution, 807
Explosives, Military, Initiation of (Corley), 87

FAWKES, C. E., and LOYD A. JONES: A sensitometric study of the reduction of developing-out papers, 503
Flashing speeds of incandescent signal lamps (Worthing), 231

FRANKLIN INSTITUTE:
Committee on Science and the Arts, Abstracts of proceedings: December 1, 1920, 134; January 5, 1921, 290; February 2, 1921, 423; March 2, 1921, 552; April 6, 1921, 714; May 4, 1921, 848
Library Notes, 137, 292, 425, 554, 716, 850
Membership Notes, 136, 291, 424, 553, 715, 850
Sections, Proceedings of meetings, 135, 290, 423, 552, 714, 848
Special meeting, December 8, 1920, proceedings, 133
Standing Committees, 1921, 422
Stated meetings, proceedings: December 15, 1920, 134; January 19, 1921, 289; February 16, 1921, 421; March 16, 1921, 551; April 20, 1921, 713; May 18, 1921, 847

GATEWOOD, WILLIAM: The modern cargo vessel, 331
Ground-plane influence on airplane wings (Zahm and Bear), 687
Guided-wave telephony (Culver), 301

Harmonic oscillations (Zahm), 381
Helium (Moore), 145
HUMPHREYS, W. J.: Meteorological acoustics, 581

Industrial wastes, Disposal of (Emerson) 807
Initiation of military explosives (Corley), 87

JONES, LOYD A., and C. E. FAWKES: A sensitometric study of the reduction of developing-out papers, 503

LEWIS, J. O.: America's petroleum problem, 357
LIEB, J. W.: Leonardo da Vinci—philosopher and engineer, 767
Liquids, Anisotropic (van der Lingen), 651

LUCKIESH, M.: The apparent form of the sky-vault, 259
MARMER, H. A.: Tidal observations off the entrance to Delaware Bay, 819
MEES, C. E. KENNETH: The structure of the photographic image, 631
MENDENHALL, CHARLES E.: Aeronautic instruments, 57
Meteorological acoustics (Humphreys), 581
Military explosives, Initiation of (Corley), 87
MOORE, R. B.: Helium; its history, properties and commercial development, 145

Navigation problems, Application of radio to (Bullard), 725
Nela Research Laboratory Notes, 833
NUTTING, P. G.: A new general law of deformation, 679

Paint films, wet, The thickness of (Pfund), 517
Petroleum problem, America's (Lewis), 357
PFUND, A. H.: The thickness of wet paint films, 517
Photographic image, Structure of the (Mees), 631
Photographic reducers, A sensitometric study of the reduction of developing-out papers (Jones and Fawkes), 503
Publications received: 143, 300, 435, 565, 724, 862

Radio, Application of, to navigation problems (Bullard), 725
Radio telegraphy. Atmospheric disturbances, or static in (Austin), 619
Radio, wired, Recent attainments in (Duncan), 23
Railway electrification, The economic aspects of (Armstrong), 493
Relativity, Einstein's principle of (Ames), 1
Signal Lamps, Incandescent, Flashing speeds of (Worthing), 231
Sky-vault, The apparent form of the (Luckiesh), 259
Slide-rule, vector (Zahm), 525
Static in radio telegraphy (Austin), 619
Stream pollution (Emerson), 807
Synthetic dye industry, The bearing of a, upon our national welfare (Bogert), 445

Telephony, Guided-wave (Culver), 301
Tidal observations off the entrance to Delaware Bay (Marmer), 819

U. S. Bureau of Chemistry, Notes: 125, 283, 543, 705, 843
U. S. Bureau of Mines, Notes: 129, 285, 419, 549, 709, 845
U. S. Bureau of Standards, Notes: 121, 265, 405, 529, 695, 823

VAN DER LINGEN, J. STEPH: Anisotropic liquids, 651
Vector slide rule (Zahm), 525

WHITE, W. C.: Some operating characteristics of electron tubes, 473
Wired radio, Recent attainments in (Duncan), 23
WORTHING, A. G.: Flashing speeds of incandescent signal lamps, 231
WYCKOFF, RALPH W. G.: The determination of the structure of crystals, 199

ZAHM, A. F.: Harmonic oscillations, 381
ZAHM, A. F.: The vector slide-rule, 525
ZAHM, A. F., and R. M. BEAR: Ground-plane influence on airplane wings, 687